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HEAVY METAL SOURCES AND FLOWS IN A MUNICIPAL SEWAGE SYSTEM

Literature Survey and Field Investigation of the Kokomo, Indiana, Sewage System

by

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16. ABSTRACT

The flow of heavy metals (Cu, Ni, Cr, Cd, Zn, PB) and cyanide in the Kokomo, Indiana, collection system and wastewater treatment plant is analyzed. The primary objective is to determine the relative contributions of domestic and non-domestic sources to the total pollutant load in the system, and to assess the levels of discharge control required for the disposal of municipal sludge by landfill or agricultural landspreading. Sampling was conducted at point source locations, in major sewer trunk- and feeder lines, and at the treatment plant. Production and waste treatment data are presented for point sources sampled for the purpose of characterizing metal and cyanide discharges as a function of these parameters. A heavy metals mass balance is attempted for the treatment plant. Metal removal factors are presented for various plant operations.

A simple statistical approach is presented for the design of a cost-effective sampling program for correlating point source and trunkline pollutant sampling. The purpose is to minimize the amount of sampling required to account for pollutants seen in trunkline and treatment plant streams in terms of discharges from specific point sources.

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report describes the flow of heavy metals (Cu, Ni, Cr, Cd, Zn, Pb) and cyanide in the Kokomo, Indiana collection system and wastewater treatment plant. The primary objective is to determine the relative contributions of domestic and non-domestic sources to the total pollutant load in the system, and to assess the levels of discharge control required for the disposal of municipal sludge by landfill or agricultural landspreading.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

The flow of heavy metals (Cu, Ni, Cr, Cd, Zn, Pb) and cyanide in the Kokomo, Indiana collection system and wastewater treatment plant is analyzed. The primary objective is to determine the relative contributions of domestic and non-domestic sources to the total pollutant load in the system, and to assess the levels of discharge control required for the disposal of municipal sludge by landfill or agricultural landspreading. Sampling was conducted at point source locations, in major sewer trunk- and feeder lines, and at the treatment plant. Production and waste treatment data are presented for point sources sampled for the purpose of characterizing metal and cyanide discharges as a function of these parameters. A heavy metals mass balance is attempted for the treatment plant. Metal removal factors are presented for various plant operations.

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SECTION 1

INTRODUCTION

Municipal wastewater treatment removes particulate and soluble materials from wastewater to the extent that discharge of this water to the natural environment poses a minimal problem. The materials removed depend on geographic location and characteristics of the population and industries served by the system.

Traditionally, emphasis has been on removal and subsequent stabilization of organic matter. Recently, interest has grown in the effects of other pollutants on the environment. Notable among these are nitrogen, phosphorus, heavy metals, and trace organics. The heavy metals are of concern owing to their toxicity. Unlike nitrogen or phosphorus, they are rarely concentrated in toxic amounts in properly operating municipal treatment systems. The stimulatory level of heavy metals is so low that the problem is one of inhibition rather than stimulation. Also, heavy metals are conservative pollutants, in that they are neither created nor destroyed. In a treatment system, they must pass through in the effluent or be retained as residue. Thus heavy metals are suited to long-term material balance studies around a wastewater treatment plant.

The purpose of this investigation was to produce a comprehensive study of the sources, flow, and effects of metals and cyanide in a municipal sewage system. To achieve this goal, the research effort was divided into three main segments: (1) A literature search to identify sources of metals to municipal sewage treatment systems, the effects of metals on sewage treatment plants and the environment, and existing or proposed legislation and guidelines for controlling this problem; (2) a field study to investigate the heavy metal mass flow pattern in and around the Kokomo, Indiana, Sewage Treatment Plant, and (3) a field study to monitor the sewer system of Kokomo, Indiana, for heavy metals and cyanide sources and flow.

SECTION 2

LITERATURE REVIEW

SOURCES OF HEAVY METALS

Metals that ultimately reach a sewage treatment plant originate from many different sources. These sources can be categorized into five groups:

- industrial discharges
- surface runoff
- domestic water supplies
- domestic additions to the carriage water
- sewer infiltration

However, the relative importance of each category can vary greatly from city to city.

Industrial Discharges

Industrial discharges are assumed to contribute the largest fraction of total metal load to a municipal treatment plant. Wastewaters from the following industries are usually the major industrial sources of heavy metals: the primary metal industries, fabricated metal products, machinery, transportation equipment, chemicals and allied products, and leather and leather products (Atkins and Hawley 1978). Of the fabricated metal industries, electroplating generally contributes the most diverse types of metals. Metal discharges from other industries have been analyzed by Klein and others (1974), and are enumerated in Table 1. Other industrial sources of heavy metal pollution include manufacturers of paper, linoleum, aniline dyes, colored glass, paint, explosives, batteries, and rubber tires (Davis 1951). Nickel-cadmium battery manufacturing is also a pollutant contributor (McCaull 1971).

Surface Runoff

Surface runoff is a significant, and often overlooked, source of metals in the environment. Klein (1974) presented data on the average concentration of metals in surface runoff, as have Wilber and Hunter (1975). The concentrations given in these two sources differed, but were roughly of the same order of magnitude, shown in Table 2. These differences are indicative of many variables, most notably land use, the effectiveness of waste removal from streets, the length of the antecedent dry period, and the intensity and duration of the storm (Wilber and Hunter 1975). Wilber and Hunter's data are based on an indepth study of two drainage areas and seven storm events, and

TABLE 1. METAL CONCENTRATIONS IN DISCHARGES FROM SELECTED INDUSTRIES (KLEIN ET AL. 1974)

Industry	Average Concentrations (mg/l) Cu	Cr	Ni	Zn	Cd
Meat processing	0.15	0.15	0.07	0.46	0.011
Fat rendering	0.22	0.21	0.28	3.89	0.006
Fish processing	0.24	0.23	0.14	1.59	0.014
Bakery	0.15	0.33	0.43	0.28	0.002
Miscellaneous foods	0.35	0.15	0.11	1.11	0.006
Brewery	0.41	0.06	0.04	0.47	0.005
Soft drinks and flavoring syrups	2.04	0.18	0.22	2.99	0.003
Ice cream	2.7	0.05	0.11	0.78	0.031
Textile dyeing	0.37	0.82	0.25	0.50	0.030
Fur dressing and dyeing	7.04	20.14	0.74	1.73	0.115
Miscellaneous chemicals	0.16	0.28	0.10	0.80	0.027
Laundry	1.70	1.22	0.10	1.75	0.134
Car wash	0.18	0.14	0.19	0.92	0.018

Klein's data on grab samples collected at many different locations. Wilber and Hunter conclude that the time profile of the heavy metals in a storm sewer after a rain is much like a unit hydrograph, that is, there is a pronounced first-flush effect. Other significant conclusions are that the majority of metals are associated with the particulate fraction of the solids which also exhibited a first-flush effect. Eller (1976) confirms that the majority of the metals is associated with the particulate fraction. Whipple and Hunter (1977) give data about the loading of metal on land areas and conclude that industrial land-use areas have more metal available to be washed into sewers than commercial or residential areas. Shaheen (1975) meanwhile presents data on the actual concentration of metal in street dust and concludes that, of the metals studied, lead was present in the highest concentration (1.2 g/cc) because of leaded fuel use. Shaheen proposes other sources of other metals: motor oil (Zn), transmission fluid (Zn), antifreeze (Cu), undercoating (Ni, Pb), rubber (Pb, Cr, Cu, Ni, Zn), asphalt paving (Ni), brake linings (Cu, Ni, Cr), and concrete (Pb, Ni, Zn). Barkdoll, et al. (1977), qualitatively substantiated these findings and also added atmospheric dustfall, accidental spills, and antiskid compounds to the list.

TABLE 2. METALS IN SURFACE RUNOFF - AVERAGE CONCENTRATIONS

	Concentration (mg/l)	
Metal	Klein (1974)	Wilber and Hunter (1975)
Cd	0.025	----
Cu	0.46	0.15
Cr	0.16	0.03
Ni	0.15	0.08
Zn	1.60	0.62
Pb	----	0.90

Bradford (1977), in a study to develop a predictive model for pollutant loading from runoff in urban areas, presents data to sustantiate that heavy metal loading relates to land use and traffic volume. Heavier industry and increased traffic cause higher levels of heavy metals in solids collected from the streets. Sartor and Boyd (1972) also found high levels of chromium, copper, zinc, nickel, lead, and cadmium in street dust collected from nine cities at an average total heavy metal load of 1.6 lbs/curb mile.

Public Water Supply

Another source of heavy metals is the domestic household. These metals originate from the metal present in the water supply and from metal added by the consumer through the use of the water. The Environmental Protection

Agency (EPA) has set maximum contaminant levels in drinking water for several of the metals, shown in Table 3 (EPA 1976). These standards, which became effective on June 24, 1977, superseded the Public Health Service Drinking Water Standards of 1962, shown in parentheses in Table 3.

TABLE 3. MAXIMUM PERMISSIBLE LEVELS OF METAL IN DRINKING WATER (EPA 1976)

Metal	Concentration (mg/l)	
Cd	0.010	(0.010)
Cr	0.050	(0.050)
Pb	0.050	(0.050)
Zn	No Standard	(5.00)
Cu	No Standard	(1.00)
Ni	No Standard	(No Standard)

The existence of these standards is evidence that heavy metals can and do exist in municipal water supplies. Bartow and Weigle (1932) showed that many ground- and surface-water supplies in Missouri, Kansas, and Oklahoma contain up to 50 mg/l of zinc. Later work by Barnet et al. (1969) showed that the tap water of Denver, Colorado, contained up to 22 μg/l Cu, 100 μg/l Fe, and 20 μg/l Zn. McCabe, et al. (1970), in a survey of water supplies in nine metropolitan areas across the country, found concentrations of lead, copper, cadmium, and chromium above the then existing standards. Some of their data are summarized in Table 4. Klein et al. (1974) estimated that the water supply contributed 20 percent of the copper and 7 percent of the zinc which entered the wastewater treatment plants. For Klein's data, this is equivalent to 0.061 mg/l Cu and 0.032 mg/l Zn in the water supply. The copper source is usually copper sulfate which is added to reservoirs to control algal growth. Finally, Newell (1971) labels hydrofluosilicic acid (used as an agent in providing fluoride) as a possible, but very minor, lead source.

Consumer Products

Domestic water use adds to metals in the water supply by solution of water pipes, now primarily copper and brass or formerly lead, or by direct addition through use of household products containing metals. Epstein (1974) identifies some cosmetic products which contain metals. These include such things as shaving creams (Zn), hair dyes (lead acetates), and dandruff shampoos (Zn). McCaull (1971) also points to phosphate detergents (and to fertilizers) as a source of metal, particularly cadmium because of the ultimate source of the phosphate in deposits of fossilized marine life which were rich in cadmium (notably fish teeth). McCaull labels black polyethylene water pipes as a possible cadmium source. A very comprehensive study (Atkins and Hawley 1978) enumerate household products which contain metals. This compilation includes, but is not limited to, cadmium, chromium, copper, iron, nickel, lead, and zinc. A very small portion of this material is shown in Table 5.

TABLE 4. METAL CONCENTRATIONS FOUND IN WATER SUPPLIES OF NINE SELECTED CITIES (MCCABE ET AL. 1970)

Metal	Highest Concentration Found (mg/l)	Number of Cities Where Drinking Water Standard was Exceeded	Percentage of Cities Sampled Whose Water Violated Standards
Pb	0.64	37	1.4
Cu	8.35	42	1.6
Cd	3.94	4	0.2
Cr	0.079	5	0.2

Infiltration

Infiltration of groundwater to the system is the final source of metal to the sewer system. Newell (1971) found copper and lead at 0.011 and 0.0085 mg/l, respectively, in groundwwater in New England, proving that unpolluted groundwater can have heavy metals. A study by the U.S. Geological Survey (1972), which collected samples from 98 locations in a 120,000-square-mile area in Washington, Oregon, and Idaho, found copper, chromium, nickel, and lead at the concentrations shown in Table 6. However, in an urban environment, groundwater can become polluted with heavy metals, as shown by Lieber and Welsch (1954) and Davis (1951). These studies both centered on the Long Island area of New York and dealt with cadmium and chromium pollution of groundwater from industrial sources.

Klein, et al. (1974), were the only researchers who attempted to quantify the sources of metals to a treatment plant. They concluded that residential and industrial sources were major contributors and were about equal in magnitude. From the other studies, it is clear that these results cannot be extrapolated to other locations but must be arrived at on a case-by-case basis. This type of study should include a measurement, or at least an estimation, of the metal loads associated with the five direct sources discussed here. Only in this way can a true picture be presented for a given location.

TABLE 5. METAL-CONTAINING CONSUMER PRODUCTS

Metal	Product	Compound
Cadmium	Shampoo	Cadmium laurate Cadmium stearate
	Dyes, tints-hair	Cadmium chloride
	Lawn Pesticides	Cadmium succinate
Chromium	Metal Cleaners	Chromic acid
	Caulking Compounds	Chromium
	Paint	Many compounds depending on color
Copper	Dyes, tints-hair	Cupric chloride
	Skin Ointment	Copper capryolate
	Foot Powder	Copper salts
	Hemorrhoid Treatments	Copper sulfate
	Antacid	Cupric phenolsulfonate
Nickel	Dyes, tints-hair	Nickel
	Paint	Nickel oxide (yellow and brown)
Zinc	Floor Cleaners	Zinc stearate
	Toilet Bowl Cleaners	Zinc chloride
	Skin Cream	Zinc oxides
	Spray Deodorant	Zinc phenolsulfonate
	Mouthwash	Zinc oxide
	Shampoo	Zinc pyrithione
Lead	Paint	Depends on color
	Roach Killer	Lead arsenate
	Dyes, tints-hair	Lead acetate
Iron	Face Powder	Iron oxide
	Dyes, tints-hair	Ferric chloride Ferrous sulfate
	Mascara	Iron oxide
	Eyebrow Pencil	Iron oxide

TABLE 6. UNPOLLUTED GROUNDWATER METAL CONCENTRATIONS (NEWCOMB 1972)

Metal	Concentration (mg/l) Max.	Min.
Cr	0.03	0.002
Pb	0.022	0.001
Cu	0.03	0.004
Ni	0.13	0.004

EFFECTS OF HEAVY METALS

Heavy metals have three effects on a municipal sewage treatment plant. The primary effect is on the process itself, that is, the inhibitory effect of heavy metals to anaerobic or aerobic biological processes. Second, the effect on the sludge produced is of concern. This effect manifests itself in the method used for ultimate disposal, which might be limited by a high metal concentration. Finally, the effects of heavy metals on the aquatic organisms and downstream users must be considered.

Metal Effects at Waste Treatment Plants

Concentrations--

The sources of heavy metals can contribute enough that a fairly high concentration enters the treatment plant. Typical influent concentrations are abundant in the literature, and Table 7 summarizes some of these data. These concentrations vary somewhat from city to city, but for a given metal are of roughly the same order of magnitude. For example, iron generally is present at a concentration greater than 1 mg/l, whereas the concentration of cadmium is only rarely greater than 0.050 mg/l.

Table 8 summarizes removal efficiencies at the plants shown in Table 7. It is obvious that there is a wide range in removal efficiencies at different plants. Cadmium is reported to be removed between 0 to 80 percent, chromium 13 to 88 percent, copper 13 to 86 percent, nickel 0 to 53 percent, zinc 41.3 to 75 percent, iron 47 to 85 percent, and lead 0 to 92 percent. Obviously there is no universal removal efficiency for a given metal.

Because of the variable influent concentration and the widely variable removal efficiency, there is a wide range in the concentration of metals in the effluent. These are calculated from the data in Tables 7 and 8 and are presented in Table 9. Here, again, there is no universal metal concentration in a treatment plant effluent.

TABLE 7. INFLUENT METAL CONCENTRATIONS TO TREATMENT PLANTS AT SELECTED CITIES

City	Cd	Cr	Cu	Ni (µg/l)	Zn	Fe	Pb
Anderson, Ind.	9.5	1180	2820	2790	1500	---	160
Buffalo, NY	18	208	137	50	337	---	99
Dayton, Ohio	27	---	---	---	---	---	---
Grand Rapids, Michigan	---	400	500	500	1200	---	---
Muddy Creek, Ohio	8	---	---	---	---	---	---
Muncie, Ind.	---	240	260	140	1150	---	930
Pittsburg, Pennsylvania	21	95	127	78	648	---	119
Wahiawa, Hawaii	5-65	12-18	62-90	60-70	200-320	1000-1180	40-70
Winnipeg, Man.	---	166	210	32	329	---	117
Avg. of 6 Cities Near Kansas City	20.2	220	146	---	733	---	210
Burlington, Ont.	6	290	310	330	2400	1540	230
Survey of 20 Plants in Ont.	20	970	300	110	1120	6580	170

TABLE 8. OVERALL METALS REMOVAL EFFICIENCIES TO TREATMENT PLANTS AT SELECTED CITIES

City	Treatment Received	Removal Efficiency (%)						
		Cd	Cr	Cu	Ni	Zn	Fe	Pb
Anderson, Indiana	Secondary Treatment	59	88	86	41	75	--	75
Buffalo, New York	Secondary Treatment	37.7	62.2	61.0	11.0	41.3	--	73.8
Dayton, Ohio	Trickling Filters	40.7	---	---	---	---	--	---
Grand Rapids, Michigan	Secondary Treatment	---	19-66	13-57	18-41	35-51	--	---
Muddy Creek, Ohio	Conventional Act. Sl.	62.5	---	---	---	---	--	---
Muncie, Indiana	Secondary Treatment	---	78	68	0	70	--	82
Pittsburgh, Pennsylvania	Secondary Treatment	67	67	56	10	65	--	81
Wahiawa, Hawaii	Step Aeration	59	32	74	42	71	85	73
Winnipeg, Man.	Pure Oxygen	---	68	77	0	80	--	49
Avg. of 6 Cities Near Kansas City	-----	16	37	49	---	47	--	49
Burlington, Ontario	Conventional Act. Sl.	80	79	73	16	77	73	93

TABLE 8, CONTINUED

City	Treatment Received	Removal Efficiency (%) Cd	Cr	Cu	Ni	Zn	Fe	Pb
4 Ontario Cities	Lagoon Systems	0	13	13	40	42	70	0
5 Ontario Cities	Primary Treatment	13	69	30	21	42	47	48
11 Ontario Cities	Activated Sludge	28	76	80	53	67	79	70

TABLE 9. CALCULATED EFFLUENT METAL CONCENTRATIONS AT SELECTED CITIES

City	Effluent Concentration (μg/l)						
	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Anderson, Indiana	3.9	142	395	885	375	---	40
Buffalo, New York	11.2	78.6	53.4	44.5	704	---	25.9
Dayton, Ohio	16	---	---	---	---	---	---
Grand Rapids, Michigan	---	136-325	215-435	295-410	588-780	---	---
Muddy Creek, Ohio	3	---	---	---	---	---	---
Muncie, Indiana	---	53	83	140	345	---	167
Pittsburgh, Pennsylvania	7	31	56	70	227	---	23
Wahiawa, Hawaii	2-27	8-12	16-23	35-41	53-93	150-177	11-19
Winnipeg, Man.	---	53	48	32	66	---	60
Burlington, Ontario	1	61	84	277	552	416	16
Los Angeles	50	290	320	280	460	700	60

The above conclusions of no universal value can be drawn for the sludge from data presented in Table 10 illustrating this point. The data are drawn from somewhat different cities than those in Tables 7 through 9. In the literature, there is no consistent basis for expressing the metal content of the sludges and it is not possible to convert these data to a common basis. Also, the sludges arise from different points in a treatment plant, such as from the waste activated or the final filter cake, thus making comparison meaningless.

Olthof (1978) summarizes some of the above data and calculates an "Accumulation Factor." This is simply the ratio of total metal concentration in the sludge (on a mg/kg dry weight basis) to the total concentration (mg/l) of metal removed from the influent. His data show that the accumulation factor of most sludges is about 10,000 and even suggests that this value may be used in design when better data are unavailable. His values are shown in Table 11.

Removal Mechanisms--

The great variability in reported metal concentrations indicates that there is no simple single removal mechanism for heavy metals and that different waste treatment plants will experience different degrees of toxicity to biological treatment systems, depending on the heavy metal values at a particular site. Therefore, the literature was searched as it pertains to heavy metal removal mechanisms and the toxicity of heavy metals.

The mechanisms of heavy metal removal seem to be the subject of much debate. This topic is clouded by the types of studies undertaken to quantify heavy metal removal. For example, some authors use bench-scale (Cheng, Patterson, and Minear 1975; Neufeld and Hermann 1973) systems with synthetic feed, others use pilot plants (Moore 1961; McDermott et al. 1963, 1962, 1965), while still others attempt to analyze data from existing treatment plants (Nomura and Young 1974; Brown and Hensley 1973; Oliver and Cosgrove 1974). Accordingly, some studies incorporated the effect of primary sedimentation while others did not. The incomplete data often reported further obscures analysis, that is, insoluble versus dissolved metal, or the solids concentration in the influent, effluent, or in-process streams. However, three predominant removal mechanisms emerge from the literature: precipitation, flow adsorption (enmeshment and adsorption), and ion exchange on metal oxides (most notably oxides of iron).

In primary treatment, settling of insoluble metals or metals absorbed to particulates is the most generally accepted removal mechanism (Nomura and Young 1974). Brown and Hensley (1973), in a study of primary treatment plants, found that as suspended solids removal increases, so does heavy metal removal. Their work also indicates that secondary plants which have better suspended solids removal experience increasing heavy metal removal, which asymptotically approaches complete metal removal. This points to the removal of soluble metal in addition to particulate metal in a secondary plant. In a series of articles, Stones (1955, 1958, 1959a, 1959b) investigated, in addition to other work, the removal of metals by sedimentation. He found that chromium, copper, nickel, and zinc are removed at 28 percent, 45 percent, 27 percent, and 41 percent efficiency, respectively.

TABLE 10. SLUDGE METAL CONCENTRATIONS AT SELECTED CITIES

		Metal Concentration						
City	Descriptor	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Bryan, Ohio	Digested Sl. (mg/l)	---	---	27	2	220	---	---
Buffalo, New York	Waste Act. (mg/kg Dry)	100	2540	1570	315	2275	---	1800
Burlington, Ontario	Digested St. (mg/kg Dry)	2.1	127	159	39	1205	471	90
Grand Rapids, Michigan	Digested (mg/l)	---	2700	2500	1700	5700	---	---
Richmond, Indiana	Digested Sl. (mg/l)	---	95	88	4	73	---	---
Rockford, Illinois	Digested Sl. (mg/l)	---	358	105	28	390	---	---
Toledo, Ohio	Sludge Cake (mg/kg Dry)	21	1170	440	320	2580	90000	630
Wahiawa, Hawaii	Digested Sl. (mg/l)	1.95	0.71	9.50	1.02	36	350	3.70
Winnipeg, Man.	Digested Sl. (mg/l)	---	2200	522	64	2500	---	675
Unidentified	Trickling Filter Sl. (mg/kg DWB)	---	250	330	50	970	27900	70

TABLE 10, CONTINUED

		Metal Concentration						
City	Descriptor	Cd	Cr	Cu	Ni	Zn	Fe	Pb
6 Cities Unidentified	------- (mg/kg)	6-135	116-788	229-1849	---	745-15270	---	324-2595
8 Indiana Cities	Final Sludge (mg/kg DWB)	16-846	---	662-8381	80-3184	1553-20119	---	545-7431
Avg. 150 Plants in U.S.	Anaerobic (mg/kg DWB)	106	2070	1420	400	3380	16000	1640
	Aerobic (mg/kg DWB)	135	1270	940	150	2170	11000	720
6 Ontario Cities	Waste Act. Sl. (mg/kg DWB)	0.36	87	31	6.6	103	534	19

TABLE 11. HEAVY METAL ACCUMULATION FACTORS IN SLUDGE

City	Type of Sludge	Accumulation Factor*
Muncie, Indiana	Digested Secondary	9000
Grand Rapids, Michigan	Digested Secondary	17800
Sioux City, Iowa	Digested Primary	9520
Bryan, Ohio	Digested Secondary	7400
Richmond, Indiana	Digested Secondary	16000
Rockford, Illinois	Digested Secondary	8500
Shelby, Ohio	Raw Secondary	11000

* Ratio of metal concentration in sludge to that in plant influent.

This action was found to be nonbiological in origin since similar results were arrived at with sterilized as well as raw sewage. However, this does not eliminate the possibility that metals do not adsorb onto settleable biological material. Oliver and Cosgrove (1974) indicate that less than 1 percent of dissolved metals, with the exception of chromium and iron, are removed by primary sedimentation, and when a slug of metal enters a plant, the dissolved fraction passes unchanged through the primaries. Jenkins et al. (1964) showed that contact of a heavy metal solution containing copper, chromium, nickel, and zinc with domestic sewage caused precipitation of the metal hydroxides. It should be noted that very high metal concentrations were studied (up to 100 mg/l) and that background metal concentrations existed up to 2.43 mg/l. Chen, et al. (1974), in studies investigating the size distribution of heavy metals, have shown that only 20 to 40 percent of the total metals in the primary effluent are dissolved. Nickel and lead are exceptions because greater than 80 percent are dissolved. While this indicates that the removal mechanism is sedimentation, it does not confirm this because no data on the size distribution of metals in the raw sewage were presented to show that the percent of dissolved metals increased through primary sedimentation. However, Oliver and Cosgrove (1974) do state that "for most metals, the proportion of dissolved to total metal increases as they pass through the system," and the data of Chen, et al., show this effect. The above studies all point to precipitation and sedimentation of metal-adsorbing particles as the removal mechanism active in primary treatment.

Within the biological treatment system, particularly activated sludge, all three mechanisms operate to remove heavy metals, that is, precipitation, floc adsorption, and adsorption-ion exchange on metal oxides. The most widely recognized and most studied mechanism is floc adsorption. Freedman and Dugan (1968) have shown that the bacterium Zoogloea has the ability to uptake and concentrate heavy metal ions beyond those which are needed for use as enzyme cofactors within the cells. The authors demonstrated that the uptake of metal increases because of net increase in cell-floc weight rather than cell numbers, since under varying environmental conditions the cell floc weight is often not proportional to cell numbers. This essentially is the justification for others' work where metal uptake is related to mixed-liquor-suspended solids rather than cell counts. Cheng, et al. (1975), and Neufeld and Herman (1975), in batch-type fill and draw reactors, both show that the uptake of heavy metal by the biological floc is essentially an instantaneous phenomenon and the rate is relatively independent of metal species or concentration. Salotto (1964) studied the relationship between organic loading on toxicity of copper to the activated sludge process, and concluded that organic loading did not markedly affect the toxicity of copper but that under conditions of higher loading, and higher effluent COD, there was less metal removal. Also, Cheng, et al. (1975), and Patterson (1978) both showed that the uptake of heavy metals was dependent upon the mixed-liquor-suspended solids concentration as well as the pH. These facts all point to adsorption as a possible removal mechanism.

Cheng, et al. (1975), and Patterson (1978) theorize that ion-exchange can explain the above facts. They develop very similar models (essentially only the notation is different) to simulate this phenomenon. It is based on the fact that the metal bound per unit weight of ion exchange medium to the metal in solution is a constant at equilibrium. In a system in which complexing ligands are also present, there will be competition between the ligands and the ion-exchange media for the metal ions. The equilibrium concentrations will be determined by the relative magnitude of the stability constants for the metal-ligand and metal-exchange media complex. The stability constant is essentially an equilibrium constant for the reaction between a soluble metal and the ligand or exchange media. Theoretically, activities rather than concentrations should be used because of the surface chemistry involved.

In an activated sludge system, the exchange media is the mixed-liquor-suspended solids and the ligands are the soluble COD or TOC. Stability constants based on these gross parameters have been termed conditional stability constants by Patterson. This system qualitatively explains the fact that effluent metal increases with increasing effluent COD (or BOD) (Patterson 1978). Cheng, et al. (1975), experimentally determined stability constants for nickel, while Patterson (1978) did so for copper. It should also be noted that the constants are a function of pH because of the competing reactions involving the hydrogen ion at the binding sites, and that as the pH increases (and $[H^+]$ decreases), the stability constant increases. This implies better removal of heavy metals at higher pH values.

Neufeld (1977) approaches the phenomenon of heavy metal uptake by activated sludge as an adsorption phenomenon, and chooses the liquid-phase metal concentration and the quantity of metal associated with the biomass (mg metal/g biomass) as the important variables. He postulates that the reaction rate depends upon the liquid phase metal concentration to some power and the degree of saturation of the biomass with metal raised to a different power. This amounts to the difference of rate expressions for the given forward and reverse reactions. At equilibrium, the rate will be equal to zero and thus the liquid phase concentration can be related to the concentration associated with the biomass. If the two exponents in the rate expression are numerically equal, the expression reduces to the equation of the Langmuir isotherm, and the constants can be evaluated as such. In general, it was found that the exponents were not equal and a more involved method must be used. Neufeld quantitatively evaluates the model for several metals. The results show the low affinity characteristic of nickel and the high affinity for lead.

The activated sludge system removes inert and biodegradable solids (Grady and Lin 1977) and can thus remove metal that is in a suspended form. This applies whether the metal enters the aerators as carry-over suspended solids from the primary, or is precipitated in the aerator because of the changed chemical environment. The accepted mechanism of removal is floc enmeshment of the solid material.

The tendency for a metal to precipitate in an aeration basin is dependent upon many parameters, such as pH, oxidation-reduction potential, and the dissolved anions which are present (Hem 1963). Within an aeration basin, the pH is usually near the neutral range, while metal hydroxides have a minimum solubility at higher pH values (Sawyer and McCarty 1967). This alone does not determine whether the metal is soluble or not, because the value of the minimum solubility changes drastically for different oxidation states of a given metal, as well as ligand effects. The oxidation state of a given metal in solution is dependent primarily on the oxidation-reduction potential. (The presence of carbonates, sulfates, chlorides, etc., can alter the behavior of a pure metal. Water system and quantitative theoretical predictions about heavy metal precipitates in an activated sludge system are difficult to make.) However, one of the interesting primary metals of the seven to be studied is iron because of its displayed tendency to be oxidized to the ferric state and precipitated as a hydroxide or oxide within the pH or ORP ranges of an aeration basin (Pourbaix 1966) (neutral to alkaline pH and -43 to +160 mv ORP (Backmeyer and Drautz 1961)). Thus the activated sludge system will concentrate this iron precipitate in the secondary settler.

An iron oxide or hydroxide precipitate can help heavy metal removal through the activated sludge process. This fact was noted during studies in which ferric chloride was being evaluated for phosphorus removal at Grand Rapids, Michigan (Green et al. 1973). This study showed enhanced heavy metal removal when iron was added to the aerators. Stumm (1967) has noted that the hydrous metal oxides show a strong tendency to interact with cations and anions in solution, depending on the pH and isoelectric point. When the metal oxide is positively charged, anion exchange occurs, and when it is negatively charged (i.e., at a pH greater than the isoelectric point), cation exchange is predominant. Similarly, Jenne (1968) has noted that hydrous oxides of iron and manganese act as a medium which adsorbs heavy metals in soil and water systems. Also, pH and Eh (oxidation reduction potential) are the most significant variables, but organic chelates, the concentration of a particular metal, and the concentrations of competing metals influence the degree of uptake. Posselt and Weber (1974) modeled cadmium uptake by hydrous metal oxides of iron and manganese and found that it could be fit to a Langmuir isotherm equation. They also noted that the limiting sorption capacity and sorption affinity tend to increase as pH is increased beyond the zeta potential. This is in qualitative agreement with the work of Stumm and Jenne.

In summary, there are three removal mechanisms active during biological treatment. The major and most widely recognized is adsorption onto the biological floc. A second is carry-over of insoluble metal which is removed by floc enmeshment. The last is the sorption of trace amounts of metal on hydrous metal oxides, particularly iron. All three mechanisms depend upon secondary sedimentation to ultimately remove the metal-laden suspended solids.

There is little information regarding removal of heavy metals through a gravity filter. Oliver and Cosgrove (1974) believe that in order for a tertiary treatment process to achieve a high degree of heavy metal removal, it must be aimed at removing the dissolved metals. Data presented by Argaman and Weddle (1973) indicate removal efficiencies on the order of 0 to 60 percent for filters, however, the data are taken from filters operating at physical-chemical pilot plants. It would be reasonable to assume that the maximum degree of metal removal in a filter would occur when all suspended matter is removed, leaving only the dissolved metal.

Toxicity--

The potential of heavy metal as a toxicant of aerobic organisms has been known for some time. Jenkins and Hewitt (1942) studied the toxic effects of chromium on trickling filters and activated sludge. Edwards and Nussberger (1947) indicated chromium as the cause of a treatment plant upset at Tallmans Island. Coburn, in 1949, noted that excessive copper, zinc, and iron have caused problems at the Fostoria, Ohio, treatment plant. However, these and many similar ones of the same period had just begun to investigate the subject of heavy metal toxicity and were often qualitative in nature.

The problems of toxicity studies with a diversity of life forms are discussed by Barth. He points out that life has been obvserved in many environments encompassing temperatures of -18°C to 104°C, pH of 0 to 13, pressures of 0 to 1,400 atm, and Eh potentials of -500 to +500 mv. Therefore, in any toxicity study on mixed cultures, there can be organisms which survive even the most severe conditions. Ingols and Fetner (1961) show that two species of bacteria respond in very different ways to the same environmental stress, in this case, a high chromium concentration. Thus the effect of the toxicant is not as clear-cut as stimulation, inhibition, and death when studying a single organism, but is manifested in a modified reaction of the culture as a whole to a given stress.

The various authors in the field have not chosen a consistent measure of toxicity, and as a consequence results are often difficult to compare. For example, one author may use effluent quality and another oxygen uptake as parameters. Barth (n.d.) also points out that, in general, aerobic systems, because of the diversity of species present, will respond to a toxicant by being only slightly inhibited at a low level of toxicant and then reaching a plateau of relative insensitivity before total failure at a high concentration. In contrast, because of their limited species diversity, anaerobic systems will often fail suddenly and completely as a given concentration of toxicant is exceeded. This effect has been observed in the literature.

In the early 1960s, a series of studies was conducted by the Robert A. Taft Sanitary Engineering Center (1965) in Cincinnati to investigate the toxicity of heavy metals to biological treatment processes (Moore 1961; McDermott 1963, 1962, 1965; Salotto 1964; English 1964; Barth 1964). Chromium, copper, zinc, and nickel were studied in pilot-scale, activated sludge systems with primary settlers. The investigators used effluent COD, BOD, and turbidity as the measure of toxicity, that is, an increase in these criteria was assumed to be a result of the toxic effect of the heavy metal. Table 12 (Taft 1965) presents the level of metals that gave a statistically significant increase in COD, BOD, or turbidity measurements. The studies also showed that the activated sludge system could withstand a total heavy-metal concentration of up to 10 mg/l, either singly or in combination, as long as the toxic levels of any particular metal are not exceeded, with about a 5 percent decrease in organic removal efficiency.

TABLE 12. CONCENTRATIONS OF METAL THAT WILL PRODUCE SIGNIFICANT REDUCTION IN AEROBIC TREATMENT EFFICIENCY

Metal	Continuous Dose mg/l	Slug Dose mg/l
Cr	10	>500
Cu	1	>75, <160
Ni	1-2.5	>50, <200
Zn	5-10	160

Slug doses of four-hour duration were also studied for each of the four metals. A slug of 100 mg/l of chromium caused a slight decline in BOD removal efficiency for about 20 hours, followed by full recovery. Slug doses of copper in concentrations greater than 50 mg/l caused severe impairment of plant operation, with recovery only after about 100 hours. Zinc and nickel in slug doses of 160 mg/l and 200 mg/l, respectively, caused serious reductions in treatment plant efficiency, followed by recovery after 40 hours for both metals. In one of the studies (English 1964), an intentional slug dose of chromium was fed to a 0.8 MGD activated sludge plant in Bryan, Ohio. The slug consisted of 150 gallons of chromic acid anodizing solution fed into the municipal sewer system. At the peak of the slug, the sewage had a concentration of 500 mg/l chromium and a pH of 5.7. Ninety-five percent of the metal was removed by the system, with no long-term adverse effects. No deterioration of treatment plant parameters was noted, with the exception of an increase in suspended solids for a short period after receiving the slug.

One of the studies was aimed at substantiating the pilot-scale results by monitoring four municipal treatment plants receiving metallic wastes. These plants receive the metallic constituents on a continuous basis with frequent slug doses. The results indicate that in the range of 1 to 9 mg/l of heavy metals there is no serious reduction in treatment plant efficiency.

Jenkins and Hewitt (1942) were the first to allude to the fact that the concentration of metal alone is not the only factor determining toxicity. They noted that a given concentration of metal had a greater effect on an activated sludge system than on a trickling filter, and concluded that it was because of the more concentrated microbial phase in the trickling filter. Ayers (1965) concluded that toxicity of copper, and by extension the other heavy metals, is affected by the sewage strength, as well as by mixed liquor and copper concentrations. This is best explained by considering the work of Cheng, et al. (1975), and Patterson (1978) concerning the effect of chelating agents on effluent metal concentration, as discussed previously. Directo (1962) also noted the relationship between influent metal concentration, influent COD, aerator-suspended solids, and effluent COD, and showed that higher suspended solids, lower influent metal concentration, and lower feed COD all result in less toxicity, as measured by effluent COD increase. Dugan (1975) has shown that when a polymer matrix surrounds a cell, the metal ions accumulate with the polymer and do not reach the cell membrane surface. This, in part, explains the high tolerance of such cells for ions that are normally toxic.

Hartmann (1968) first attempted to characterize the type of inhibition caused by heavy metals according to the Michales-Menton scheme of enzyme kinetics. The conclusion was that different metals exhibited different types of toxicity, i.e., either competitive, uncompetitive, or noncompetitive, depending upon whether the slope, vertical intercept, or both of the Lineweaver-Burke plots are functions of the inhibitor concentration. Discussions of this article by Patterson and Brezonik (1969) and Banerji (1979) clarify some of the points made by the original authors.

Neufeld and Hermann (1975) expanded the original studies of Hartmann (1968) with the aim of using the modified Michales-Menton kinetics for design. Michales-Menton kinetics relate the specific growth rate to the substrate concentration by the following relationship:

$$V = \frac{V_M F}{K_M + F}$$

These are slightly different than the nomenclature of the Monod relationship commonly used, but the concepts are equivalent. In this case:

V = forward reaction rate; measured as grams of volatile suspended solids produced per mg of chemical oxygen demand satisfied per minute ($gVSS/mgO_2/min.$)

V_M = maximum forward reaction rate obtained at high substrate concentrations

K_M = the substrate concentration which corresponds to one-half of the maximum forward reaction rate; measured as mg chemical oxygen demand per liter (mg COD/l)

F = substrate concentration; measured as mg COD/l.

The resulting concentration of organisms measured as volatile suspended solids can be related to the mean cell residence time and hydraulic residence time by:

$$X\Theta = \frac{(F_o - F)\,Y_G}{1 + b\Theta_C}$$

where F_o = feed concentration (mg COD/l)

Θ = hydraulic residence time (day)

X = volatile suspended solids concentration (mg/l)

Y_G = true growth yield; mg of VSS produced

b = specific decay rate in mg VSS decayed per mg VSS present per day (day $^{-1}$)

The author determined the constants V_M, K_M, Y_G, and b as functions of the metal to suspended solids ratio. Results were presented for mercury, cadmium, and zinc. These values were then used to compute predicted effluent COD as a function of sludge age with metal concentration as a parameter. No metal interactions were studied, as only one metal at a time was considered.

Heck, et al. (1972), refuted the conclusions of Hartmann (1968) and Neufeld and Hermann (1975) and concluded that the inhibition is independent of effluent substrate concentration. However, he was working with glucose, which has a very low K_M, and therefore he could not have investigated the very low substrate concentrations necessary to show Michales-Menton kinetics. He also concluded that total metal controlled the log growth rate. An analysis of the data shows this conclusion was reached because at higher soluble copper concentrations, there was no change in the rate constant for substrate removal. However, there was an increase in effluent COD and thus in organic chelating compounds which would make the soluble copper increase but would not affect the available or free copper. He did show that the initial lag period (and hence acclimation time) was a function of the metal concentration. Malaney, et al. (1959), also noted that the lag period was a function of the metal concentration.

Poon and Bhayani (1971) investigated the toxic effects of metals on two bacteria, Zooglea ramigera and Geotrichum candidum, using Michales-Menton models. They concluded that the toxic behavior of metals varies with the biological species present. However, as was pointed out by Chaudhuri and Engelbrecht (1971), these studies were done on pure cultures using a simple substrate, and any extrapolation to mixed cultures on a complex substrate is risky.

Edwards and Nussberger (1947) noted the disappearance of Sphaerotilus when chromium was present in high concentrations, as did Moore, et al. (1961). Neufeld (1940) showed that excess heavy metals could cause "deflocculation" of activated sludge. However, this is different from bulking sludge where many filamentous organisms are present. Deflocculation is characterized by fine, stabilized pinpoint floc in the overflow of secondary clarifiers. Thus this work does not contradict previous studies.

Heavy metals exert a toxic effect on the nitrifying organisms, Nitrosomonas and Nitrobacter, independent of the effects on carbon-removing organisms. This was noted by Jenkins in 1942, by Moore, et al. (1961), and by Edwards and Nussberger (1947) for chromium. It has been reported that nitrification is inhibited at the concentration shown in Table 13 (Roper 1977; Water Pollution Control Federation 1977). These levels are much lower than those for BOD removal, and substantiate the premise of Barth presented earlier.

TABLE 13. SIGNIFICANCE OF HEAVY METALS RELATIVE TO NITRIFICATION (ROPER 1977; NEUFELD 1976)

Metal	Concentration at Which Inhibition Occurs (mg/l)	
	Single Stage Nitrification	Two Stage Nitrification
Zinc	0.08-0.50	0.3-2.0
Lead	0.50	2.0
Chromium	0.25	1.9
Copper	0.005-0.5	0.33-3.33
Cadmium	---	---
Nickel	0.25	0.42

There is little in the literature about heavy metal inhibition of trickling filter operations. While Stones (1955, 1958, 1959a, 1959b) shows that trickling filters can remove heavy metals, no mention was made on the effect of those metals on the organisms present. Jenkins and Hewitt (1942) show that 1 mg/l chromium has no effect on nitrification or removal of organic matter. However, 10 mg/l causes a reduction in the concentration of nitrate and 100 mg/l inhibits nitrification by 70 percent. They also noted that, as nitrification was inhibited, there was a slight rise in the concentration of nitrite present. This indicates that Nitrobacter is the more sensitive organism.

The potential toxicity of heavy metals to anaerobic digestion has long been recognized. Wischmerger and Chapman (1947) noted that sludge digestion, as measured by gas production, was not retarded at total nickel concentration up to 500 mg/l. Rudgal (1946) reported a great improvement in digester performance in a Wisconsin town when a sewage trunkline containing a high copper load was bypassed into Lake Michigan. Originally there was 3,000 mg/l of copper in the digester, and it was producing only 0.5 ft^3 of gas per pound of volatile suspended solids added. After bypassing, the gas production rose to 10 ft^3/#VSS added. Stander (1956) showed that toxicity of copper was first noted between 4,100 and 13,300 mg/kg on a dry solids basis. For that study, this was about 80 to 270 mg/l. O'Neill (1957) noted that a 1 percent copper level on a dry solids basis inhibited digester gas production. He also concluded that zinc appears to exert a greater effect than copper.

A series of articles (Moore 1961; McDermott 1963, 1962, 1965) investigated the level of metal in the influent sewage which is inhibitory to anaerobic digestion. Table 14 presents these data. It was also shown that an anaerobic system does not show a plateau region in response to metal toxicity, but either proceeds normally or fails entirely and that even though the total metal concentration is high, the soluble metal concentration is low.

TABLE 14. HIGHEST CONTINUOUS DOSE OF METAL THAT WILL ALLOW SATISFACTORY ANAEROBIC DIGESTION OF SLUDGES (NEUFELD AND HERMANN 1975; MOORE 1961; MCDERMOTT 1963, 1962)

	Concentration in Influent Sewage mg/l		Digested Sludge Metal Concentration mg/l	
Metal	Primary Sludge Digestion	Combined Sludge Digestion	Soluble	Total
Chromium	>50	>50	3	420
Copper	10	5	0.7	196
Nickel	>40	>10	1.6	70
Zinc	10	10	0.1	341

Lawrence and McCarty (1965) showed that the soluble metals were responsible for digester inhibition and that these could be effectively controlled by the presence of sulfide. Digesters which operated normally at high total metal concentrations fed as a sulfate failed rapidly when the metal was fed as a chloride. However, sulfide is toxic at high levels (Lawrence et al. 1964) and can sometimes inhibit a digester. Grady and Lim (1977) present data showing the soluble metal concentration which is inhibitory to anaerobic digestion. These data are shown in Table 15. However, Taylor (1965) shows that soluble zinc causes failure when present in excess of 1.5 mg/l. Gould and Genetelli (1975) investigated the distribution of seven heavy metals according to size in an anaerobic digester. More than 90 percent were associated with the particulate matter (>100 micron), and for all metals, except copper, zinc, and lead, the percent in the dissolved state (<20 angstroms) was below the detection limit. Only 0.1 percent of the total copper, 0.06 percent of zinc, and 0.3 percent lead were dissolved.

TABLE 15. CONCENTRATIONS OF SOLUBLE HEAVY METALS EXHIBITING 50 PERCENT INHIBITION OF ANAEROBIC DIGESTERS (GRADY AND LIM 1977)

Metal	Approximate Concentration mg/l
Fe^{++}	1-10
Zn^{++}	10^{-4}
Cd^{++}	10^{-7}
Cu^{+}	10^{-12}
Cu^{++}	10^{-16}

In summary, most authors indicate it is the soluble form of metal which exhibits toxicity, and the degree of toxicity is dependent upon many interrelated factors. The major factors are the concentration of organic matter, both dissolved and suspended, the species of organisms present, and the chemical environment.

Effects of Wastewater Sludges Containing Heavy Metals

The concentration of heavy metals in wastewater sludges can be very high, as shown in Table 10. The direct effect of these metals on treatment operations, such as anaerobic digestion, was discussed and one would expect to see inhibition of other biological processes as well. Chemical processing of sludge, while not subject to inhibition as are biological processes, may adversely affect the distribution of heavy metals in the sludge. Olver, et al. (1975), showed that chlorine oxidation of sludges releases significant amounts of metals which are ultimately recirculated within the plant and which then may be detrimental to the treatment process.

While the in-plant effects of heavy metals can be problems for a waste treatment plant, it is the ultimate disposal of the sludges which poses the greatest problems. Recently, a large body of literature has been published and much research done concerning disposal of heavy metal laden sludges to agricultural land. The key concepts which have been put forth are (Brown 1975): the ability of a plant to absorb metal from a compound depends on factors other than the solubility of the metal compound in water and that plant uptake of metals from soils depends on the portion of soil metal called plant-available metal rather than the total metal content of soils.

Another factor which must be considered is the potential for groundwater contamination by heavy metals. Olthof (1978) summarized others' work in this regard, and concluded this does not seem a limiting factor when sludge is applied to cropland. Large quantities of metals will not be leached out due to low solubility of metals in a soil-water environment. Solubility depends on properties of the soil, such as pH, humus and clay content, and cation exchange capacity.

The decision to use land application of sludge must be based on local conditions and may not be the appropriate disposal technique in every community. Climate, land use, topography, soil type, and geology are factors which must be considered. Climate determines such things as length of growing season, number of days when sludge cannot be applied, and sludge storage requirements. Topography can influence land application because of runoff and erosion problems, while geology can determine the potential for groundwater pollution. Land use includes such factors as agricultural versus forested land, reclamation or recreational use. This discussion is limited to agricultural lands. Soil can be classified by many parameters; the most important with regard to heavy metals is cation exchange capacity. This is largely a function of the amount and type of clay present in the soil.

Crop type also influences the amount of sludge which can be applied. Basically, sludge application rates are usually limited, either by the quantity of nitrogen in order not to excessively increase nitrate concentration of groundwater, or by the quantity of potentially toxic materials, usually heavy metals, specifically cadmium. The lifetime of a disposal site is usually based on the cumulative amounts of lead, copper, nickel, zinc, and cadmium applied to the soil. Limits are set forth to allow growth and use of crops at any future date. Zinc, copper, and nickel will induce phytotoxicity before their concentrations adversely affect human or animal health. Lead is a problem because of direct ingestion of soil particles by animals and sometimes humans, since essentially no plant uptake of lead occurs. The cadmium limit is derived from its lifetime uptake and concentration by crops grown in soils amended with cadmium-containing sludges and the subsequent dangers associated with cadmium being present in the food chain. The scheme used to determine the amount of sludge which can be applied to agricultural land is shown in Figure 1 (EPA 1978). Numerical restrictions are presented in subsequent sections.

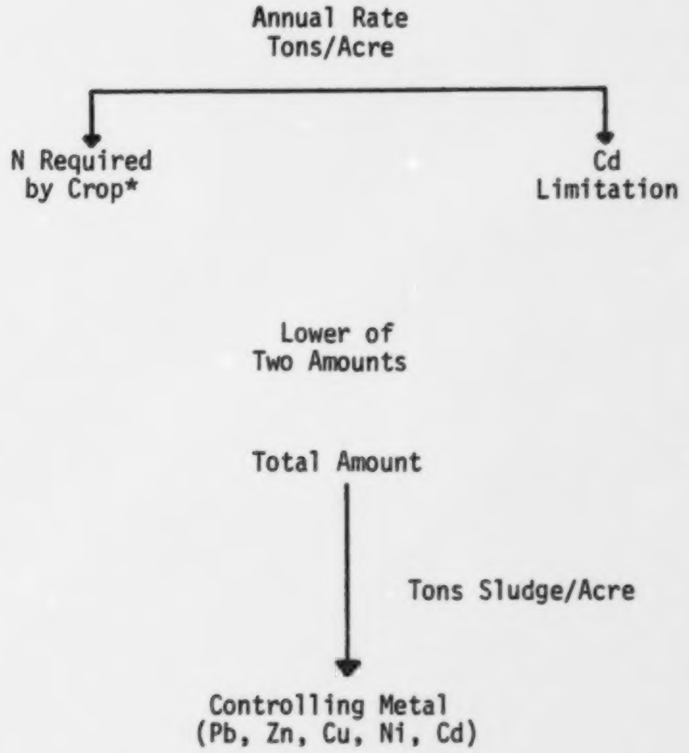
Annual Rate
Tons/Acre
N Required
by Crop*
Cd
Limitation
Lower of
Two Amounts
Total Amount
Tons Sludge/Acre
Controlling Metal
(Pb, Zn, Cu, Ni, Cd)

Figure 1. Approach used to determine sludge application rate and the life of disposal site.

* Based on many factors such as crop type, previous sludge application, surface or incorporated application, and available nitrogen.

Effects of Wastewater Treatment Plant Effluent Containing Heavy Metals

The significance of heavy metals in treatment plant effluents, like wastewater sludges, is a complex subject. There are many parameters other than metal concentration which determine toxicity to aquatic life and reuse. Some of these are hardness, pH, and salinity. There are many investigations studying the problem, as is seen in Table 16 (EPA 1976). Roper (1977) and the Environmental Protection Agency (1976) indicate that McKee and Wolf, *Water Quality Criteria* (1963), is an excellent reference summarizing the toxicity of many contaminants, including metals, to aquatic organisms. Clearly, heavy metals can exhibit toxicity on aquatic life, can enter food chains via the water route, and impair subsequent beneficial use of the water.

Regulations--

Regulations and proposed standards have been put forth to control the presence of heavy metals in the system. These regulations have originated on federal, state, and local government levels. They have addressed three areas: sludge disposal, effluent requirements, and metal input to the system. The regulations are in an almost constant state of development and refinement, and a detailed discussion would be quickly outdated. Nonetheless, some description is necessary if only for the purpose of showing the applicability of the type of data generated by this investigation.

The Indiana Water Quality Standards indicate that, "All wastes at all times and all places shall be free from all substances . . . which are in amounts sufficient to injure, be toxic to, or produce adverse physiological responses in humans, animals, aquatic life or plants." It is this section which can regulate effluent quality. The standards recommend the use of the 96 hr - LC_{50} for "biota significant to the indigenous aquatic community," and for fish to use not more than one-tenth of the 96 hr LC_{50} for "important indigenous aquatic species." The data are to be extracted from *Quality Criteria for Water* (EPA 1976) and are presented in Table 17. However, the current National Pollution Discharge Elimination System (NPDES) permit for Kokomo does not specifically limit the discharge of heavy metals.

Proposed regulations concerning sludge disposal on agricultural land have been put forth by the EPA (1977). They state that the cumulative metal loading to agricultural land depends on the type of soil present as well as type of metal considered. Soil type is characterized by the cation exchange capacity. These loadings are presented in Table 18. There is also a maximum application rate which shall not be exceeded. This is based on cadmium loadings and ranges from 0.9 to 1.8 lb/acre/yr. Indiana has set this value at 1.785 lb/acre/year (2 kg/ha/yr).

The last and most pertinent regulations concerning heavy metal pollution are those dealing with pretreatment. On June 26, 1978, the EPA (1978) set final pretreatment regulations to become effective on August 25 of that same year. This detailed set of regulations was aimed at eliminating the problem at its source. The regulations apply to nondomestic pollutants discharged into publicly owned treatment works (POTW's). The standards will be set nationally on an industry-by-industry basis, using technology-based standards, but will be enforced in most cases at the state level. The states through the

TABLE 16. EFFECTS OF HEAVY METALS ON AQUATIC BIOTA

Metal	Conc.	Effect
Cd	57 μg/l	Decreased survival of developing fathead minnow embryos
	80 μg/l	Survival and growth of bluegill sunfish larvae severely reduced
	17 μg/l	Growth and survival of channel catfish fry reduced significantly
	8.1 μg/l	Significant reduction in number of eggs produced per female of topminnow
	3.4 μg/l	Extensive mortality of brook trout during spawning
	2.0 μg/l	96-hour LC_{50} for chinook salmon
Cr^{VI}	17.6 mg/l	96-hour LC_{50} for fathead minnows
	118 mg/l	96-hour LC_{50} for bluegill
	7.46 mg/l	96-hour LC_{50} for bluegill (Cr^{III})
	0.2 mg/l	Chinook salmon juveniles significantly reduced
Cu	60 μg/l	Toxic to rainbow trout
	180 μg/l	96-hour TL_{50} brown bullhead
	710 μg/l	96-hour TL_{50} for bluegill
Fe	0.9 mg/l	Toxic to carp
	1-2 mg/l	Toxic to pike and trout
Pb	5.6-7.3 mg/l	96-hour TL_{50} for fathead minnow
	1 mg/l	96-hour TL_{50} for rainbow trout
	0.10 mg/l	Detrimental effects to brook trout
Ni	730 μg/l	Caused significant reduction in fertility of fathead minnow
Zn	870 mg/l	96-hour LC_{50} for fathead minnows
	5.50 mg/l	96-hour LC_{50} for brook trout
	10.6 mg/l	96-hour TL_{50} for bluegill
	7.8 mg/l	96-hour TL_{50} for carp

TABLE 17. WATER QUALITY CRITERIA FOR HEAVY METALS*

Cadmium	cladocerans and salmonid fishes	
	soft water*	0.4 μg/l
	hard water*	1.2 μg/l
	for other, less sensitive, aquatic life	
	soft water*	4.0 μg/l
	hard water*	12.0 μg/l
Chromium	for freshwater aquatic life	100 μg/l
Copper	for freshwater aquatic life	0.1 times a 96-hour LC_{50} as determined through nonaerated bioassay using a sensitive aquatic resident species
Iron	for freshwater aquatic life	1.0 mg/l
Lead	for freshwater aquatic life	0.01 times the 96-hour LC_{50} using the receiving or comparable water as the diluent and soluble lead measurements using a 0.45 micron filter
Nickel	for freshwater aquatic life	0.01 times the 96-hour LC_{50} of sensitive resident species
Zinc	for freshwater aquatic life	0.01 times the 96-hour LC_{50} of sensitive resident species

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*National Interim Primary Drinking Water Regulations, U.S. Environmental Protection Agency, Washington, D.C., Government Printing Office, 1976.

TABLE 18. MAXIMUM SLUDGE METAL APPLICATIONS FOR PRIVATELY OWNED FARMLAND

	Soil Cation Exchange Capacity (meq/100 g)		
	<5	5-14.9	$\geq$15
	Maximum Metal Addition lb/acre		
Lead	450	900	1800
Zinc	225	450	900
Copper	113	225	450
Nickel	45	90	180
Cadmium	4.5	9	18

Note: 1.785 lb/acre = 2 kg/hectare.

NPDES system will have the power to modify the standards to suit local conditions. Specifically a POTW has to implement a pretreatment program which reflects the removal capability by the POTW.

This regulation applies to all POTW's with a flow of at least 5 mgd and receiving any industrial wastes, and those less than 5 mgd if the situation warrants it. The POTW must (1) require compliance with federal standards, (2) control, through contract, permit, or other means, the discharge of the industrial user, (3) develop a compliance schedule for installation of technology to meet applicable pretreatment standards, and (4) inspect and monitor discharges. In addition, the POTW must (1) identify and locate all industrial users subject to the regulations, (2) identify the character and volume of the above flow, (3) set up a notification-monitoring system for those industries affected, (4) pursue legal action against noncompliers, and (5) provide sufficient funding, personnel, and expertise to carry out these objectives.

As stated above, the POTW can relax a pretreatment regulation on the basis of its removal efficiency for that pollutant according to the formula:

$$Y = \frac{X}{1 - r}$$

where Y = modified standard

X = national standard

r = POTW removal efficiency

However, when a POTW revises a categorical pretreatment standard, a partnership is formed in which both the POTW and discharger assume responsibility for meeting the pretreatment standard. It is further stated that a POTW may revise these regulations only if (1) the pollutant is consistently removed (documented removal occurs in 95 percent of representative samples taken) and the POTW cannot be by-passing any sewage or has completed an analysis to implement a by-pass control project, or (2) the sludge disposal practice is currently and will continue to meet the appropriate regulations.

On May 22, 1978, the City of Kokomo passed ordinance 4644 (amended ordinance 4126) which set the following concentration limits for industrial dischargers of heavy metals: Cd (0.5 mg/l), Cr (2.5 mg/l), Cr -6 (2.5 mg/l), Cu (2.0 mg/l), Ni (2.0 mg/l), Zn (5.0 mg/l), lead (0.5 mg/l), and iron (5.0 mg/l).

SECTION THREE

FIELD INVESTIGATION OF HEAVY METAL MASS FLOW IN AND AROUND THE KOKOMO, INDIANA, SEWAGE TREATMENT PLANT

INTRODUCTION

This investigation determines in some detail the mass flow pattern of heavy metals within a full-scale municipal treatment plant receiving a fairly high level of influent heavy metals. Specifically, a mass balance was performed around each unit operation, and around the plant as a whole. A second objective was to demonstrate that a program of this type is feasible at a treatment plant and that data are generated that can ultimately be used in formulation of a municipal sewer use ordinance to regulate point sources of heavy metals. Finally, the data generated by this study enable examination of the effect of various sludge systems and influent heavy metals on plant operation. For example, it allows comparison of heavy metal levels with changes in sludge-handling procedures.

The treatment plant selected for this study was a 30 mgd activated sludge, multimedia gravity filter plant at Kokomo, Indiana, which is located about 50 miles directly east of Purdue University in West Lafayette, Indiana. The plant location, layout, and flow diagrams are shown in Figures 2, 3, and 4, respectively. This particular plant was chosen for several reasons: the size of the community (42,000), the industrial makeup, and its proximity to West Lafayette. A medium-sized city was chosen in order to guarantee that the sewage would be of "typical" composition, i.e., that neither an overabundance of domestic nor industrial sources discharge to the sewage system. More important, Kokomo was chosen because of its industrial makeup, which includes such metal dischargers as plating shops (Cd, Cr, Cu, Ni, Zn), alloy fabricators, electronics equipment manufacturers, a steel mill, various cold-working metal shops, and printing presses. These industries contribute substantial quantities of heavy metals which have been a problem to the treatment plant for some time.

Cadmium, chromium, copper, nickel, and zinc are the five heavy metals chosen for this study because of their potential effects on the environment, particularly in land disposal of sludge and subsequent phytotoxicity of cover crops. The similarity and ease of analysis of these metals using atomic absorption spectrophotometry was also a factor because of the large number of samples expected and the necessity for rapid analysis. This was the reason for excluding mercury, a problem metal. The final reason for selecting these metals was their presence in Kokomo's sewage and sludge at atypically high levels.

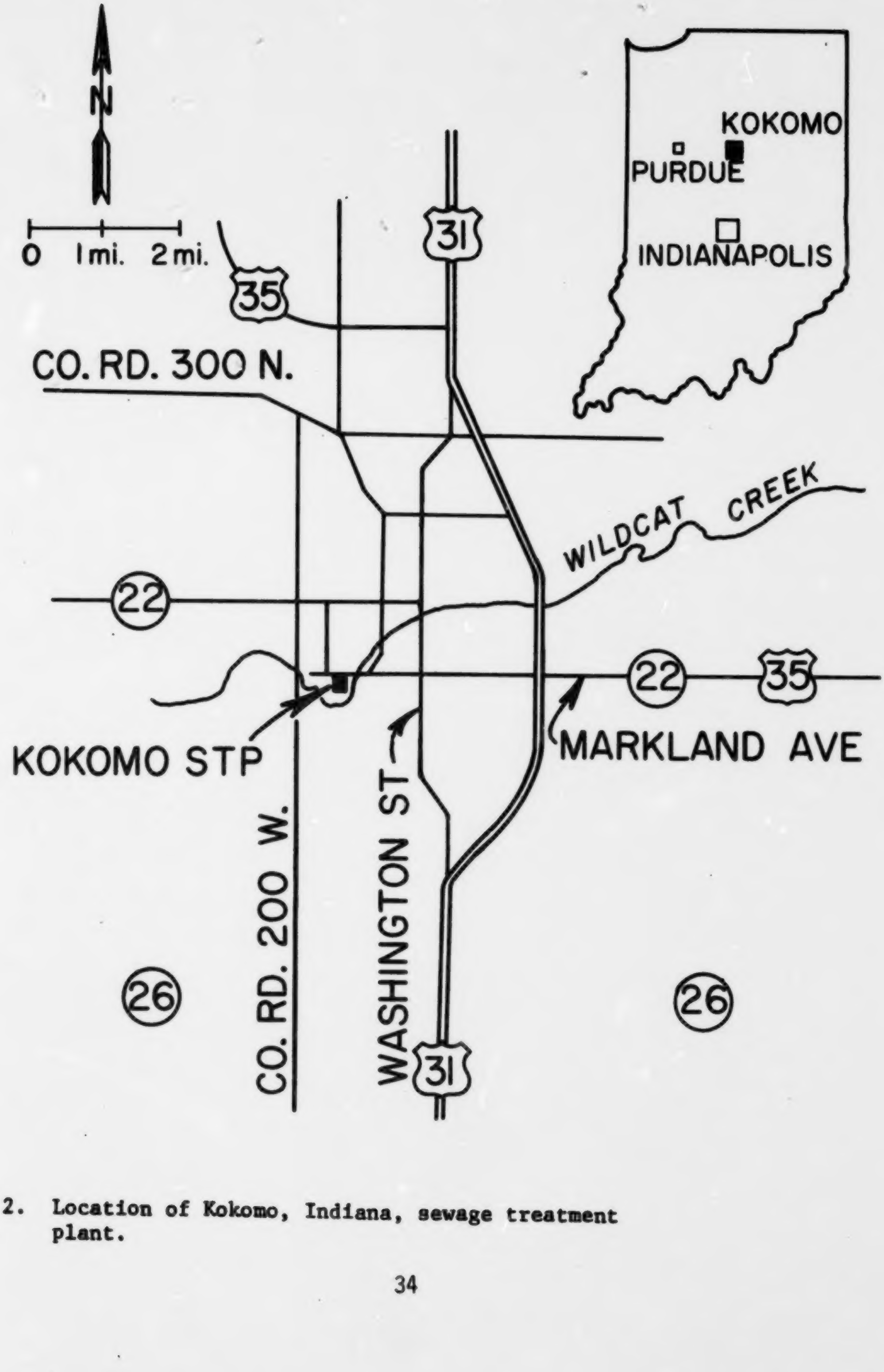
N
0
1mi.
2mi.
KOKOMO
PURDUE
INDIANAPOLIS
31
35
CO. RD. 300 N.
WILDCAT CREEK
22
22
35
KOKOMO STP
MARKLAND AVE
CO. RD. 200 W.
WASHINGTON ST
26
26
31

Figure 2. Location of Kokomo, Indiana, sewage treatment plant.

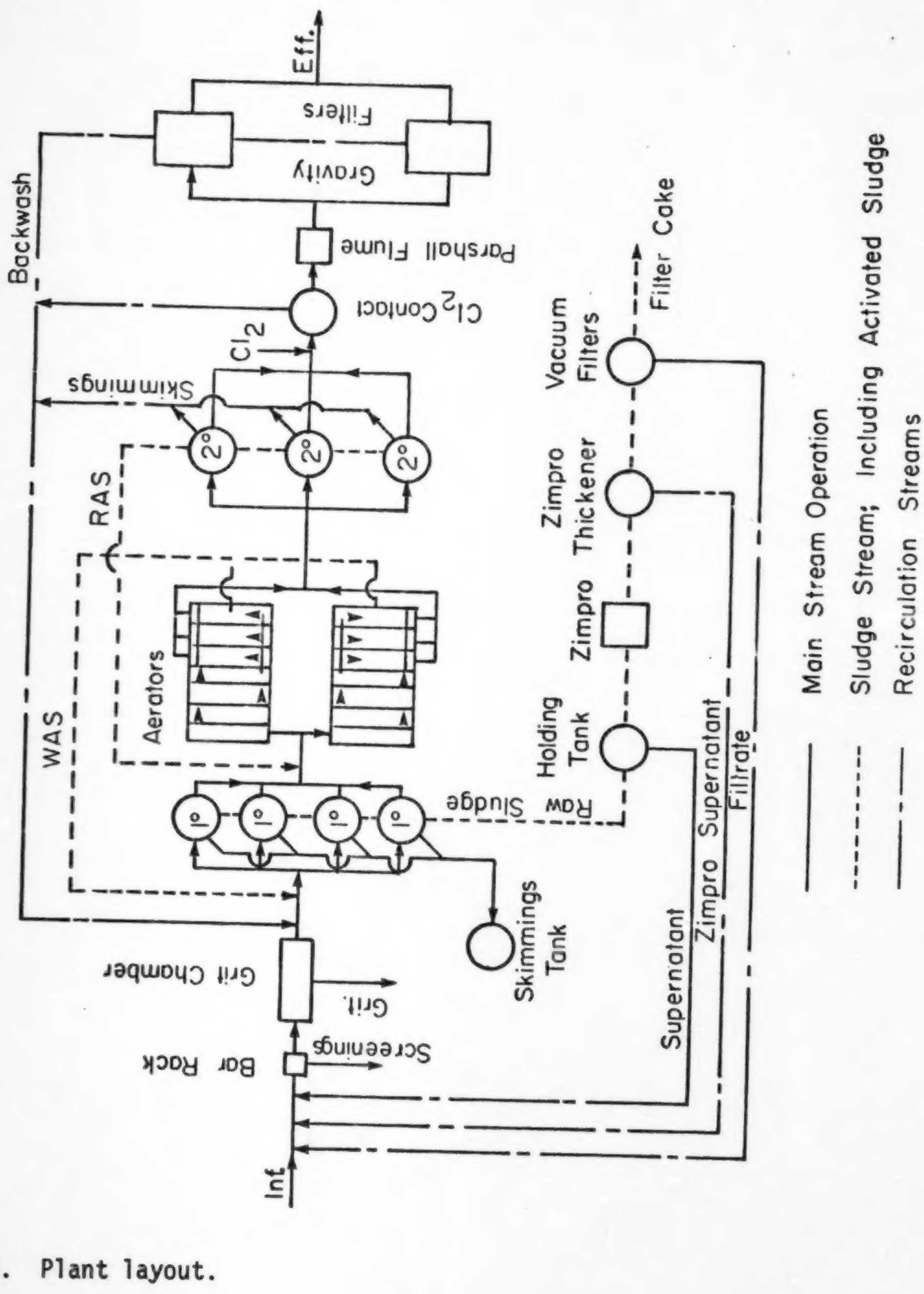
Inf.
Bar Rack
Screenings
Grit Chamber
Grit
Skimmings Tank
WAS
RAS
Aerators
1°
2°
Raw Sludge
Holding Tank
Zimpro
Zimpro Thickener
Vacuum Filters
Filter Cake
Skimmings
Cl2
Cl2 Contact
Parshall Flume
Gravity Filters
Backwash
Eff.
Supernatant
Zimpro Supernatant
Filtrate
Main Stream Operation
Sludge Stream; Including Activated Sludge
Recirculation Streams

Figure 3. Plant layout.

Chem. Add. - Chemical Addition for Phosphoruus Removal; not operational.

Cl_2 Contact - Chlorine Contact Tank.

Grit - Grit Chamber.

Pri - 1
- 2
- 3
- 4
- Primary Settlers; Numbers as per Kokomo Treatment Plant Convention.

Sec. Clar. - Secondary Clarifiers.

Skim. - Skimmings Holding Tank.

Sl. Hold. Tank - Raw Sludge Holding Tanks.

V. F. Build. - Vacuuum Filter Building.

Zimpro Service - Zimpro Service Building.

Zim. Thi. - Zimpro Thickener.

Filters - Multi-media Gravity Filters

Aerators - Activated Sludge Aeration Basins.

TL 1-6 - Trunk Line #1-6.

Figure 3, continued.

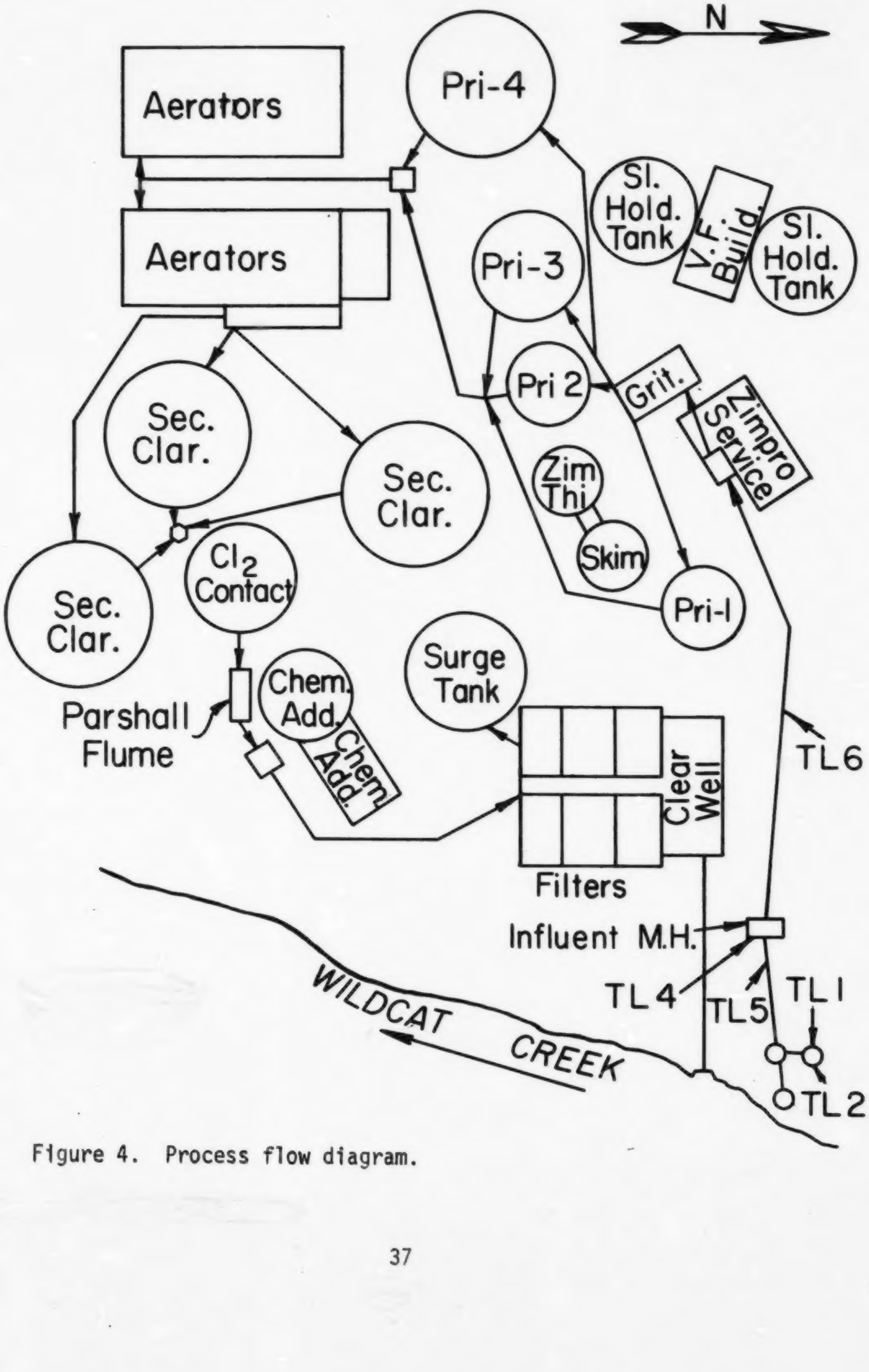
N
Aerators
Aerators
Pri-4
Sl. Hold. Tank
V.F. Build.
Sl. Hold. Tank
Pri-3
Pri 2
Grit.
Zimpro Service
Sec. Clar.
Sec. Clar.
Sec. Clar.
Zim Thi
Skim
Pri-l
Cl2 Contact
Surge Tank
Chem. Add.
Chem. Add.
Parshall Flume
Clear Well
Filters
Influent M.H.
TL6
TL4
TL5
TL1
TL2
WILDCAT
CREEK

Figure 4. Process flow diagram.

During the study, intermediate results were generated to allow evaluation and perhaps modification of the sampling program. One intermediate evaluation showed an unusually high level of metal removal across the entire plant relative to values reported at similar facilities elsewhere. This led to inclusion of iron as a metal to be measured because of its possible effects on removal efficiencies. Lead was added to the project at the same time because of other research on the sources of heavy metals to the Kokomo sewer.

The sampling period necessary for the mass balance must be at least as great as the retention time of any of the tanks of solids or liquid-handling system enumerated in Table 19 and also greater than the mean cell residence time of activated sludge. A further consideration was a sampling period of sufficient duration to minimize the effect of a widely varying metal load to the plant because of weekdays and holidays. A 60-day period was decided upon, commencing at 12 noon, August 2, 1978, and continuing through 12 noon, October 1, 1978. The mass balance for iron and lead was undertaken from September 6, 1978, through September 16, 1978, inclusive, an 11-day period encompassing days 35 through 45 of the sampling program.

TABLE 19. RETENTION TIMES OF THE VARIOUS PROCESS TANKS AT KOKOMO, INDIANA

Process Tank	Volume (MG)	Retention Time (Hours)[1]
Grit Chamber	0.18	0.3
Primaries	1.2	1.3
Aerators	5.4	3.2
Secondaries	4.7	3.1
Cl_2 Contact Chamber	0.46	0.6
Gravity Filters	0.67	0.9
Raw Sludge Holding Tank	0-2.2	0-280
Zimpro Thickener	0.33	103

[1] Based on actual hydraulic flow rate through system as reported in Table 27, and pro-rated for a 60 day period for intermittent systems.

LABORATORY APPARATUS AND PROCEDURES

The large number of samples necessitated instituting a system for orderly analysis.

Sample Preservation

Samples were brought from Kokomo on a routine basis. At Purdue they were acidified to a pH of 2 with 1:1 HNO_3. It was found that this could be accomplished through the addition of 1 ml of 50 percent nitric acid per 125 ml of sample. At the beginning of the 60-day period, the nitric acid was added directly to the empty bottles before sampling. This led to numerous and justifiable complaints from the plant personnel about acid burns and fumes. Therefore, from day 5 of sampling, acid was not added until the samples were returned to Purdue. Since it is recommended (Taras 1975; EPA 1974) that the acid be added immediately upon collection of the sample, the effect of not adding acid until late was investigated. This consisted of removing a series of aliquots from a large volume of sample. Acid was added to each of these according to the schedule in Table 20. These samples were subsequently handled in the same way as the actual mass balance samples. The results of this determination are shown in Figure 5 and indicate that no appreciable error is introduced by delaying acid addition as much as three days.

TABLE 20. ACID ADDITION SCHEDULE USED TO INVESTIGATE THE EFFECTS OF DELAYED ACID ADDITION FOR SAMPLE PRESERVATION

Sample No.	When Acid Added
1	Immediately on collection
2	12 hrs. after collection
3	26 hrs. after collection
4	72 hrs. after collection
5	121 hrs. after collection
6	20 hrs. prior to analysis (148 hrs. after collection)
7	Immediately prior to analysis (168 hrs. after collection)
8	None added

Analytical Methods

The liquid samples were composited in proportion to flow rate and analyzed. The metals which were determined (cadmium, chromium, copper, nickel, zinc, and later iron and lead) were analyzed according to the procedure outlined in Manual of Methods for Chemical Analyses of Water and Wastes (EPA 1974), with only minor modifications, as noted in Appendix A. The method entails slowly evaporating an aliquot of the sample to which 5.0 ml of concentrated HNO_3 has been added, of the sample to dryness. After the beaker

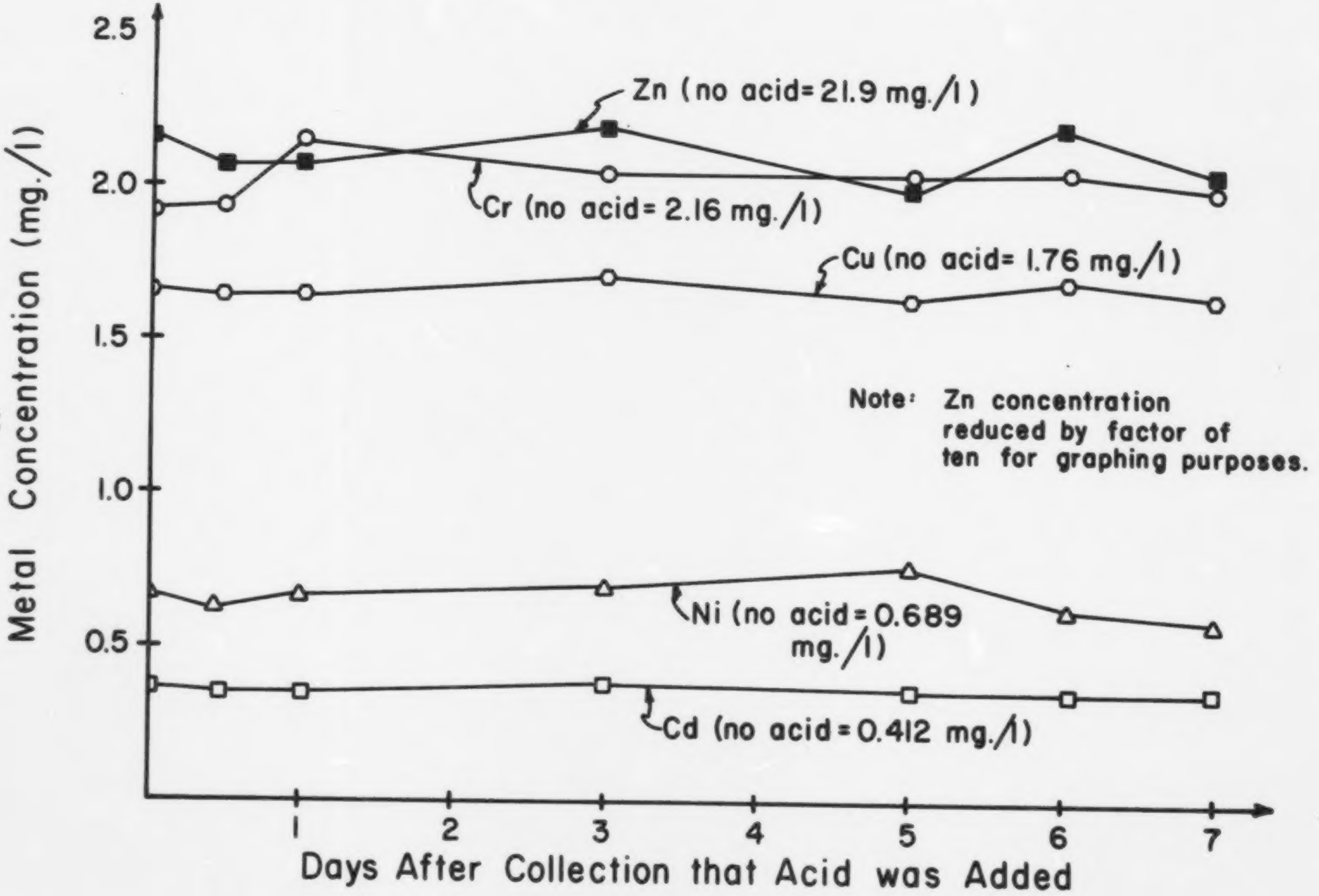

Figure 5. Effect of acid addition on metal concentration.

and sample cool, another 5 ml portion of nitric acid is added, the beaker is covered with a watch glass and refluxed for 90 minutes. Hydrochloric acid is added, and the mixture is then refluxed for another 90 minutes. The watch glass is then removed and the acid mixture allowed to evaporate to dryness. After cooling 10 ml of 1:1 HNO_3, made with double distilled de-ionized water, is added and allowed to remain in the beaker until all residue dissolves, generally for about 5 minutes. This is the sample which is analyzed and is transferred to a plastic 50 ml dilution tube. Through experience, it was found that a 1:10 dilution and 1:100 dilution was necessary so that the Atomic Absorption spectrophotometers can operate within the linear range of the absorption-metal concentration curve. These dilutions were also prepared with a 10 ml glass repipet and 1.00 ml Eppendorf pipette^R.

Vacuum filter cake samples were collected and placed in small plastic bags by plant personnel. On reaching Purdue samples were immediately placed in the freezer until analysis; no acid was added. They were then analyzed, using the modified method discussed previously and in Appendix A, after being heated to dryness so the total solids content could be determined.

Equipment

All samples were collected in wide-mouth plastic bottles of three sizes, 159 ml, 250 ml, and 500 ml, with screw-on caps. The composited samples were subsequently placed in 200 ml Berzelius beakers for digestion. Either volumetric glassware or a Mettler P-1210, 1200 g capacity balance was used to measure the amount of sample subject to digestion. All evaporations and digestions were done on four identical Corning PC-100 Hot Plates located under a standard laboratory hood. The metals were determined on two Perkin-Elmer A.A.s. The older instrument, a PE 306, was used for approximately the first 20 days of the sampling period. The second machine, a PE 603, was used for the remainder of the project. Both machines utilized a Deuterium Arc Background Corrector to correct for the high concentration of salts which developed when samples are evaporated. The settings and operational conditions of the instruments are discussed in Appendix B.

Standards were prepared from commercial stock solutions obtained from Harleco Chemicals. A working stock solution was prepared from the commercial stock solution. This, in turn, was used to prepare the sequential dilutions used in actual determinations. Table 21 shows concentrations of various metals in sequential dilutions used in the standards; these were identified as 2A, A, B, C, D, E. A sequence of six 1:1 dilutions was used. The standards were prepared as needed, with the exception of chromium, which was prepared fresh weekly.

Accuracy and Precision

The accuracy and precision of the atomic absorption technique have been determined many times and are readily available (Taras 1975; EPA 1974). Those data, however, can only be applied to the particular technique used and the individual laboratory or laboratories where the analyses were performed. To use the modified technique, it was desirable to obtain accuracy and precision data which includes all the variables of this analytical method, including the instruments, technique, and analyst. Furthermore, accuracy and precision are functions of the concentration of the metal being analyzed, and therefore determinations should be done for varying metal levels.

TABLE 21. METAL CONCENTRATION IN SEQUENTIAL DILUTIONS USED TO STANDARDIZE INSTRUMENT

Metal	Metal Concentration (mg/l) Standard 2A	A	B	C	D	E
Cd	2.00	1.00	0.500	0.250	0.125	0.0625
Cr	---	2.00	1.00	0.500	0.250	0.125
Cu	10.00	5.00	2.50	1.25	0.625	0.3125
Ni	10.00	5.00	2.50	1.25	0.625	0.3125
Zn	2.00	1.00	0.500	0.250	0.125	0.0625
Fe	100.00	50.00	25.00	12.50	6.25	3.125
Pb	40.00	20.00	10.00	5.00	2.50	1.25

The accuracy of each metal analysis was to be determined at four levels: high, intermediate-high, intermediate-low, and low. Divisions were made on the basis of the working standard, concentration "A", given in Table 21. The divisions occur at: greater than 80 percent, "A" standard; 50 to 80 percent, "A" standard; 20 to 50 percent, "A" standard; and less than 20 percent, "A" standard, respectively. The results of 15 replicate samples in each range for each metal are shown in Table 22 and Figure 6. It can be seen that the precision of the method is greatest at a higher metal concentration, but not so high that the nonlinear range is used. It is emphasized that these results are in terms of the concentration of metal in the solution being analyzed, not in the original samples since it is the concentration in the solution aspirated by the instrument which will affect the instrument and hence the precision of the method. This is the basis for determining how far to concentrate a sample.

The accuracy of the method can be estimated by addition of a known volume of a solution of a known metal concentration and then determination of the amount of metal present above the background level and comparison to the mass of metal added. When this is done, the results are expressed as "percent recovery." Ideally it should be 100 percent. The results are shown in Table 23, derived from tests run on 10 samples. It can be seen that the method is reasonably accurate.

TABLE 22. PRECISION OF METAL ANALYSES

Metal	High Abs. Range (Conc. mg/l)	High Relative[1] Stan. Dev.	Intermediate - High Abs. Range (Conc. mg/l)	Intermediate - High Relative[1] Stan. Dev.
Cd	94-205 (>0.8)	5.9%	69-84 (0.5-0.8)	4.1%
Cr	119-151 (>1.6)	4.3%	61-105 (1.0-1.6)	4.2%
Cu	232-431 (>4.0)	2.5%	123-157 (2.5-4.0)	3.7%
Ni	175-233 (>4.0)	3.6%	60-92 (2.5-4.0)	4.4%
Zn	211-269 (>0.8)	3.3%	32-74 (0.5-0.8)	7.3%

Metal	Intermediate - Low Abs. Range (Conc. mg/l)	Intermediate - Low Relative[1] Stan.Dev.	Low Abs. Range (Conc. mg/l)	Low Relative[1] Stan. Dev.
Cd	40-63 (0.2-0.5)	25.0%	0.5-3 (<0.2)	63.0%
Cr	9-29 (0.4-1.0)	22.7%	3-7 (<0.4)	40.9%
Cu	61-75 (1.0-2.5)	3.7%	1-4 (<1.0)	67.5%
Ni	25-62 (1.0-2.5)	8.7%	13-20 (<1.0)	20.6%
Zn	21-40 (0.2-0.5)	118.6%	5-9 (<0.2)	16.3%

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[1] Relative standard deviation equals the standard deviation divided by the average, multiplied by 100.

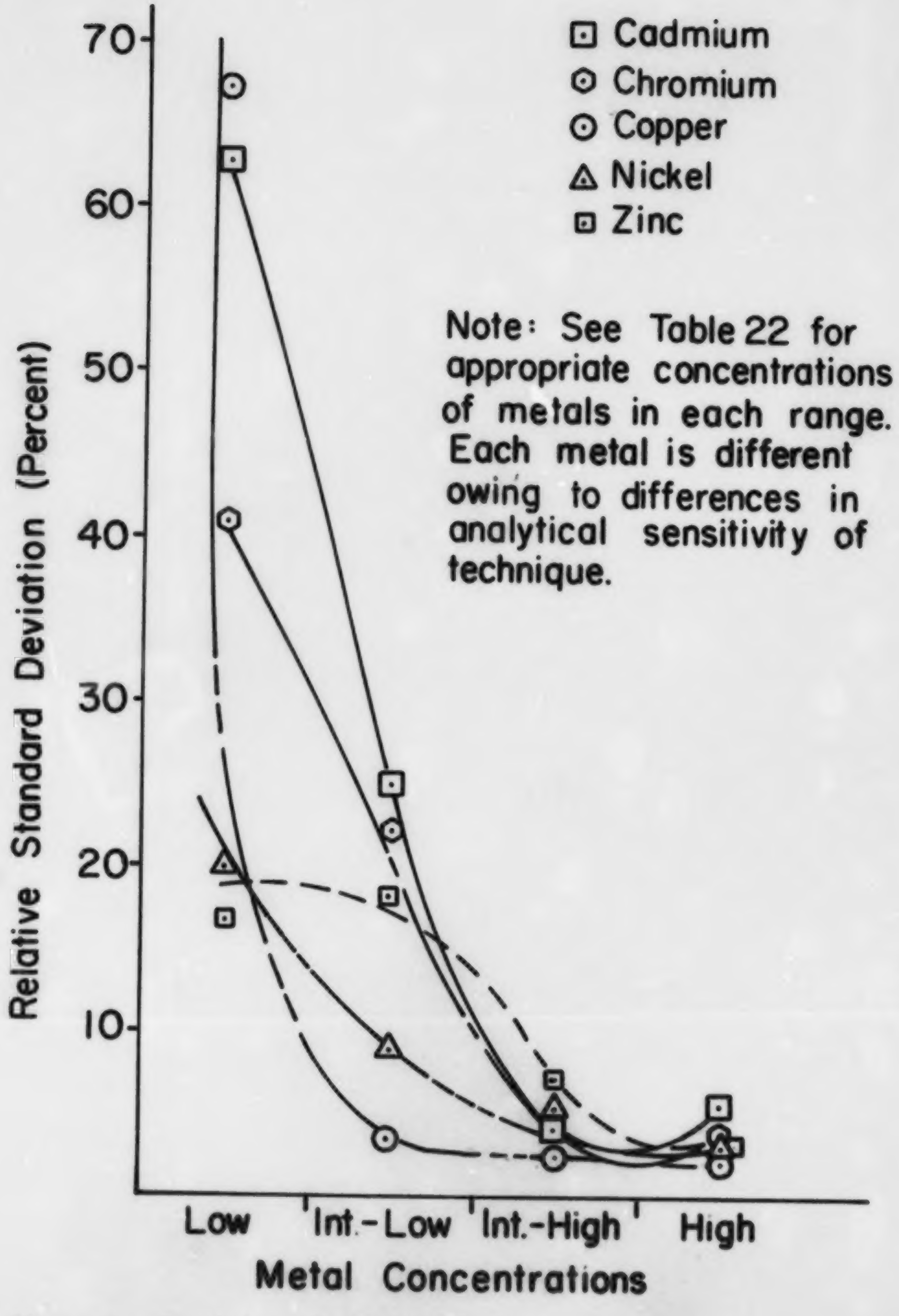


Figure 6. Precision of metal analyses.

TABLE 23. ACCURACY OF METAL ANALYSES

Metal	% Recovery[1]
Cd	93.1
Cr	93.0
Cu	96.2
Ni	97.4
Zn	96.8

[1] Percent of metal in a known synthetic spike which accounted for during analysis.

$$\% \text{ Recovery} = \frac{(\text{Conc. in spiked sample}) \times (\text{Vol. of spiked sample}) - (\text{Conc. in sample}) \times (\text{Vol. of sample})}{(\text{Conc. of spike}) \times (\text{Vol. of spike})} \times 100\%$$

SAMPLING PROGRAM

To obtain a useful heavy metal mass balance around a municipal treatment plant such as Kokomo's, each sampling point must be carefully chosen. The exact location for a sampling point must meet the following requirements:

(1) It must be easily accessible to treatment plant personnel;
(2) The flow rate at the sampling point must be determinable, and
(3) It must be located so that a representative sample can be easily collected.

Conceptual Location of Sampling Points

Before exact locations are specified, however, a decision must be made of what flow streams need to be sampled. The starting point for this is Figure 4, the plant flow diagram. This shows that there are several interconnecting recirculation loops, e.g., the filter backwash and waste sludge streams. An expanded version of Figure 4 is shown in Figure 7, which clearly labels the needed influent and effluent streams for a mass balance from every unit operation, as well as three "mixing points."

Mixing points can be thought of as a unit operation which serves the same purpose as completely mixed reactors. The use of mixing points accounts for metals in the interlocking loops. For example, mixing point 2 connects the grit chamber effluent and the primary influent, the connection being the pounds of metal present in the waste-activated sludge and filter backwash.

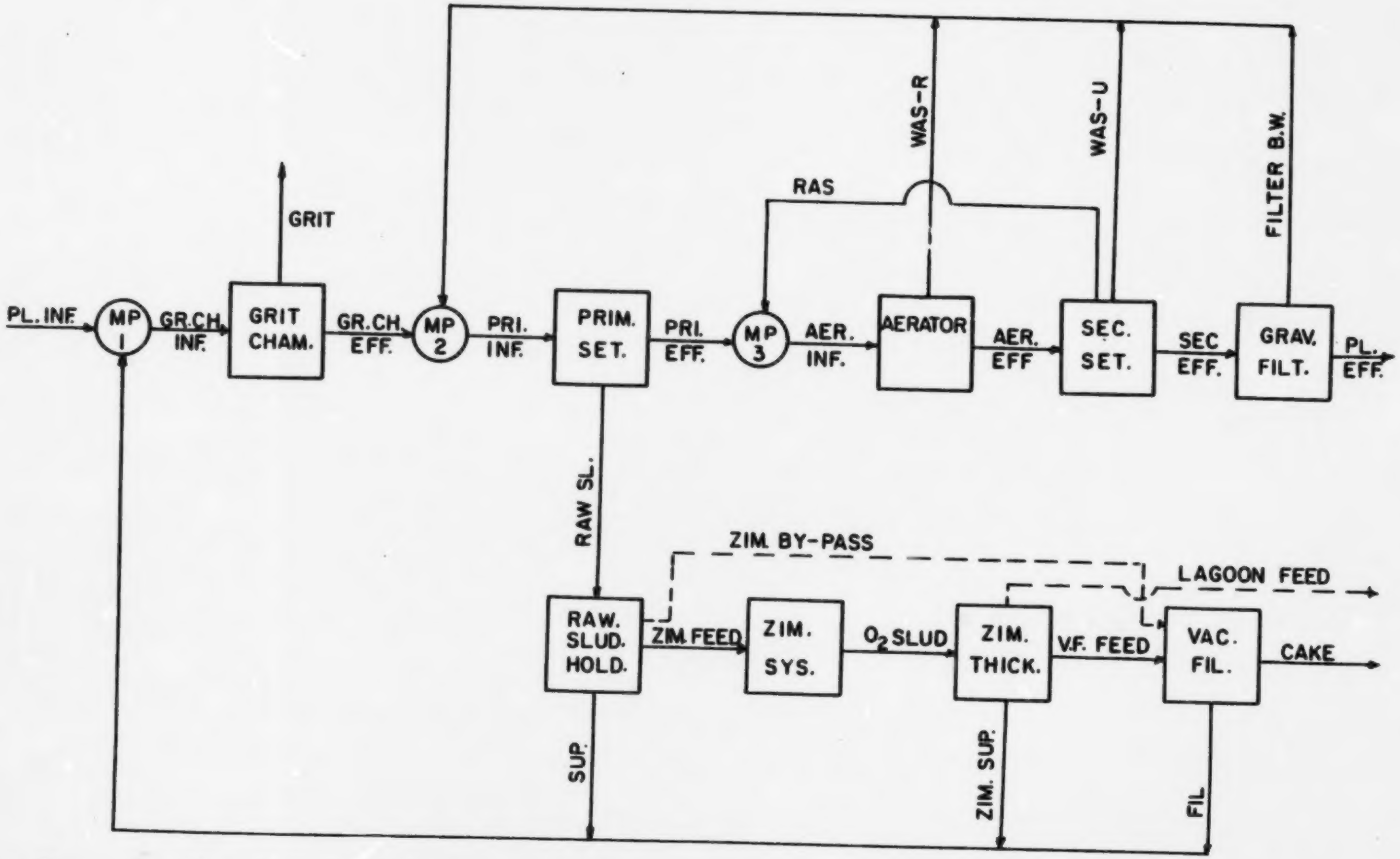

PL. INF.
MP 1
GR.CH. INF.
GRIT CHAM.
GRIT
GR.CH. EFF.
MP 2
PRI. INF.
PRIM. SET.
PRI. EFF.
MP 3
AER. INF.
AERATOR
AER. EFF
SEC. SET.
SEC EFF.
GRAV. FILT.
PL. EFF.
RAS
WAS-R
WAS-U
FILTER B.W.
RAW SL.
RAW. SLUD. HOLD.
ZIM. FEED
ZIM. SYS.
O_2 SLUD
ZIM. THICK.
V.F. FEED
VAC. FIL.
CAKE
ZIM. BY-PASS
LAGOON FEED
SUP.
ZIM. SUP.
FIL

Figure 7. Mass balance diagram.

PL. INF. - Plant Influent
GR. CH. INF. - Grit Chamber Influent
GR. CH. EFF. - Grit Chamber Effluent
PRI. INF. - Primary Influent
PRI. EFF. - Primary Effluent
AER. INF. - Aerator Influent
AER. EFF. - Aerator Effluent
SEC. EFF. - Secondary Settler Effluent
PL. EFF. - Plant Effluent
GRIT - Grit
WAS-R. - Waste Activated Sludge from Aerators
WAS-U. - Waste Activated Sludge from Underflow
FILTER B.W. - Filter Backwash
RAW SL. - Raw Sludge
ZIM. FEED - Zimpro Feed Sludge
O_2 SLUD. - Oxidized Sludge
V.F. FEED - Vacuum Filter Feed
CAKE - Filter Cake
SUP. - Raw Sludge Holding Tank Supernatant
ZIM. SUP. - Zimpro Thickener Supernatant
FIL. - Filtrate
ZIM. BY-PASS - Zimpro By-Pass
LAGOON FEED - Lagoon Feed
MP 1 - Mixing Point 1
GRIT CHAM. - Grit Chamber
MP 2 - Mixing Point 2
PRIM. SET. - Primary Settlers
MP 3 - Mixing Point 3
AERATOR - Aerators
SEC. SET. - Secondary Settlers
GRAV. FILT. - Gravity Filters
RAW SLUD. HOLD. - Raw Sludge Holding Tank
ZIM. SYS. - Zimpro System Reactors
ZIM. THICK. - Zimpro System Thickener
VAC. FIL. - Vacuum Filters

Figure 7, continued.

Theoreticaly, a mixing point could be placed at the intersection of any of the recycle streams, such as the Zimpro supernatant and vacuum filter filtrate.

Four streams are not shown in the flow diagram of the plant. Two of these are the primary and secondary skimmings streams. The secondary skimmings flow to the same recirculation loop as do waste-activated sludge and filter backwash. The primary skimmings are sent to a 81,000 gal holding tank. The skimmings were excluded from the sampling program because of the very small volume relative to the other streams. The consequent long retention time of the holding tank (it is emptied by a contractor about once per year) tends to make this stream's metal load insignificant. However, as later data show, there are relatively high levels of metals in the skimmings thus disposal of skimmings should be carefully evaluated. Another stream not shown flows from the chlorine contact chamber eventually to mixing point 1. Periodically, plant personnel open a valve which allows any sludge accumulated at the bottom of the chlorine contact tank to be recirculated to the system. It was felt that the intermittent nature of this stream, as well as its relatively low flow rate, would be insignificant in any mass balance performed about the chlorine contact tank. A fourth stream not shown is the screenings from the bar rack. Screenings consist almost entirely of rags and debris which constitute a very small portion of the influent waste flow and are inconsequential in terms of the heavy metals mass balance.

Two other streams, indicated by dashed lines in Figure 7, are necessary because plant operation problems forced modifications in the system causing layoff for short periods. The Zimpro bypass stream arose early in the project when the Zimpro system was out of service and it became necessary to lime the raw sludge so it could be vacuum-filtered and disposed. The lagoon-fed stream arose when mechanical problems were experienced with the vacuum filters, and as a result, the Zimpro thickener was overloaded. Thus it became necessary to pump sludge from the thickener to the old sludge lagoon at the rear of the treatment plant.

Two other terms will eventually be necessary to complete the mass balance. These are accumulation terms for the Zimpro thickener, which was initially empty, and for the raw sludge holding tank, which has a floating cover and, therefore, has a variable inventory.

Physical Location of Sampling Points

Figure 7, the detailed flow diagram, Figure 3, the plant layout and the criteria listed at the beginning of this section describe each sampling point. The method of flow measurement is covered in a subsequent section.

There are two distinct systems within the treatment plant. One is the mainstream system which functions to reduce the concentration of pollutants in wastewater. The other system handles sludge, and its function is to increase the solids concentration and hence metal level. The consequence of this distinction is that the flow rate in the first stream is essentially conserved from influent to effluent, while in the sludge stream it is radically reduced.

The first sampling point is the plant influent. The first choice was to sample at the wet well of the pump station, however, the wet well is mixing point 1 (MP1). Therefore, it was necessary to find an upstream sampling point, a manhole on the plant site through which pass five of the six trunk lines that serve Kokomo. The sixth trunk line serves only domestic sources and does not contribute significant metal or hydraulic loads to the plant, as shown in Table 24. It was decided that this manhole would serve as the sampling site. It is also the site at which the plant has routinely sampled its influent in the past.

TABLE 24. HYDRAULIC AND METAL LOADING TO TREATMENT PLANT FROM ONE TRUNKLINE NOT ENTERING THROUGH PLANT INFLUENT MANHOLE

Day	Flow MGD	Metal Load (#/day) Cd	Cr	Cu	Ni	Zn	Pb
1	0.380	0.002	0.02	0.15	0.02	0.30	0.05
2	0.478	0.001	0.008	0.118	0.014	0.122	0.016
3	0.406	0.001	0.014	0.141	0.025	0.166	0.027
Avg.	0.421	0.001	0.014	0.136	0.020	0.196	0.031
Percent of Total Plant	2.4%	0.02%	0.01%	0.56%	0.02%	0.07%	0.44%

The influent and effluent to the grit chamber were sampled at respective ends of the chamber. Care was needed in sampling the effluent because of the design of the grit chamber in Kokomo. The sample must be taken upstream of the overflow at the grit chamber effluent, because the downstream side of the overflow is essentially mixing point 2, where the waste sludge and filter backwash streams re-enter the mainstream.

Samples of grit were periodically collected on a grab basis. The grit was raked to the influent end of the aerated grit chamber and then mechanically lifted to a screw conveyor which transported it to a small truck next to the building. Due to moving equipment, it was unsafe to sample from the screw conveyor, and due to the nonhomogenous state of the grit, once in the truck, sampling was done as it dropped from the screw conveyor onto the truck. Because of the small mass flow rate, only a rough estimate of metal in the grit was necessary.

Influent to the primaries was perhaps the most difficult point to sample. There was no place open to sample between mixing point 2 and the primaries and no splitting box between mixing point 2 and the four primaries. Consequently, it was necessary to sample at each primary and composite the samples. A scheme was devised to composite samples as they were collected to minimize the number of bottles. Since samples should be composited by flow rate, it was necessary to assume that the overflow rate for each primary was equal. This implies that the samples could be composited according to surface area of the settlers. Only 500 ml bottles were used, and they were marked with appropriate lines and in a designated order, shown in Figure 8.

The primary effluent was sampled at the collection box located near the aeration building. It was necessary for plant personnel to ascertain that no floating material was collected in the sample.

The aeration influent, aeration effluent, and waste activated sludge were, in effect, samples of the mixed liquor. Only one sample was collected due to the homogenous nature of the mixed liquor with respect to the heavy metals. At Purdue, this sample was composited according to both the aeration influent flow rate and the WAS flow rate. The two different composites reflected the difference in flow rate of the two streams. Each composite was analyzed individually.

The return activated sludge was sampled at a pre-existing sampling port in the aeration building basement. When sampling at this point, first it was necessary to open a faucet and let it run for about 30 seconds to empty the 20 ft vertical section of sampling pipe leading from the RAS line to the sampling point.

At times, sludge was wasted from the underflow of the secondary clarifiers (WAS-U stream). When this occurred, a portion of the RAS samples was composited according to the flow rate of the WAS-U stream and analyzed separately.

The secondary effluent was sampled at the Parshall Flume where there was a good deal of turbulence, assuring a representative sample. The flow rate was also measured here to assure accuracy.

The plant effluent was sampled at the clear well of the gravity filters. From there it flows through an outfall to Wildcat Creek. The clear well was chosen rather than the outfall simply because the Kokomo plant routinely samples at that point.

The filter backwash was sampled at the surge tank adjacent to the filter galleries because of its convenient location. It also gives a more representative sample than would the filter itself due to the changing characteristics of the backwash water.

The preceding sampling points constitute the sampling program for the main stream operations. Eight other sampling points constitute the sludge-processing system. The two systems are interfaced through the raw sludge stream and mixing point 1.

The raw sludge was sampled at a pre-existing sampling port adjacent to the piston pumps which pump the sludge from the primary clarifiers to the raw sludge holding tank. These are located in the basement of the vacuum filter building. One sample was taken each time sludge was pumped from a different

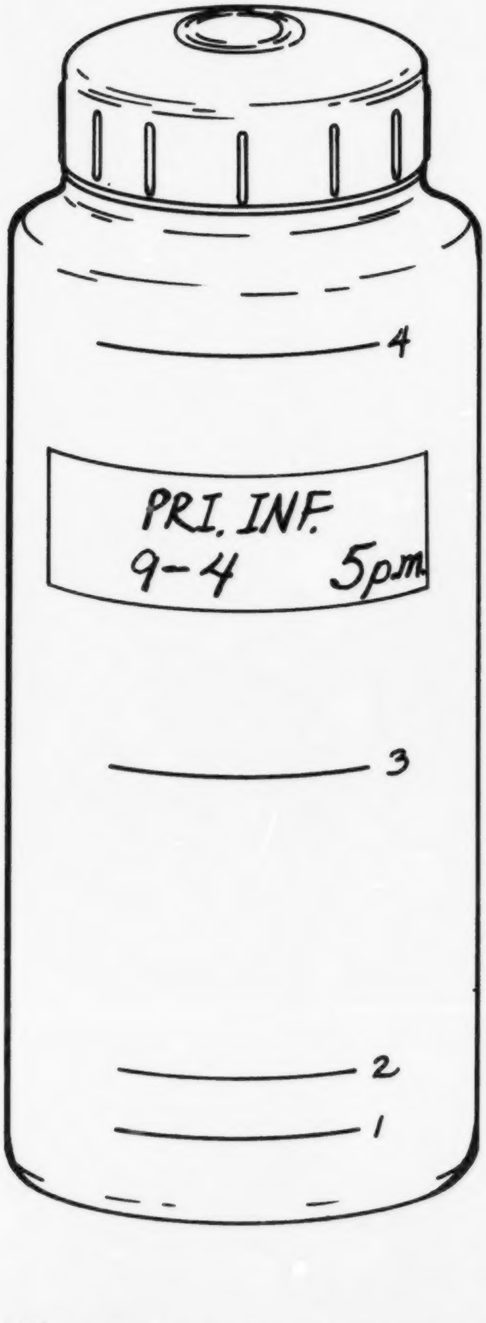

4
PRI. INF.
9-4 5p.m.
3
2
1

Figure 8. Bottle used to sample primary influent.

primary. Sampling was done near the midpoint of the pumping period to avoid getting an excessively dilute or concentrated sludge sample.

Periodically the plant would supernate a volume of liquid from the raw sludge holding tanks to the wet well. Then a sample was collected at a sampling port installed in the basement of the vacuum filter building in the pipe leading to the wet well. Samples were collected at approximately the midpoint of the supernating operation.

The Zimpro feed and oxidized sludge streams, the influent and effluent from the Zimpro reactors, respectively, were sampled at pre-existing sampling ports in the Zimpro service building by the operators. Needless to say, these samples were only collected when the Zimpro system was on-line.

The Zimpro supernatant sample was collected by the operators at a sump adjacent to the Zimpro thickener. This supernatant was collected as it flowed over a triangular weir constructed in the sump for flow measurement purposes. There were periods when this stream was not flowing, even when the Zimpro was operating, due to the liquid level in the thickener being drawn down by feeding the vacuum filters. Samples were collected only when there was a flow.

The vacuum filter feed was sampled directly from the vacuum filter troughs. This gave the most representative sample for this stream because of the mixing of the sludge in the trough caused by rotation of the filter. Again, this sample was collected only when the filters were operational.

The sample of the filtrate from the vacuum filter was collected from the same point as was the supernatant from the raw sludge holding tank for two reasons. First, the filtrate and the supernatant flow through the same pipe to the wet well, and second, the piping system is arranged so that only one of the operations can be done at a time. Thus there is no mixing of the two streams.

The last major stream is the filter cake. At Kokomo, the cake is removed from the vacuum filters and then transported to trucks by a conveyor belt. The vacuum filter operators removed typical pieces from the conveyor and place them in plastic bags, which were sealed and transported to Purdue for analysis.

The Zimpro bypass which occurred when the plant limed the sludge, was sampled in a manner analogous to the vacuum filter feed, i.e., in the trough of the vacuum filters The lagoon feed was never actually sampled since this stream was discovered after the project began. The sludge was pumped from the bottom of the Zimpro thickener to the lagoon, and because of this, the metal concentration was estimated as the average concentration fed to the vacuum filters.

The accumulation in the raw sludge holding tank was estimated as the average concentration of raw sludge fed to it thoughout the 60-day period. The concentration of accumulation in the Zimpro thickener was assumed to be identical to that of the vacuum filter feed because initially the thickener

Was empty and during the last ten days of the project, sludge was continually added from the Zimpro system while none was removed by vacuum filters, thus the thickener was nearly filled with the thickened sludge. This was verified as the grit chamber influent increased dramatically from the previous 50-day level. The increased solids lost over the weir of the thickener due to the buildup of sludge in it caused this.

Flow Measurement

During the 60-day study, the Kokomo plant was still in a facilities expansion program and not all electrical control systems were operational, so often there was no direct measure of a stream's flow rate. This necessitated a system of addition and subtraction of known flows to determine an unknown one.

When the project started, the only automatic flow-measuring devices which were completely operational were the Parshall Flume, the totalizer meter measuring filter backwash, and the Zimpro flow measurement devices. Other systems were only partially operational, such as measurement of the waste sludge stream, or not operational at all, such as meters monitoring flow to the primaries. Even though flow meters on the waste-activated sludge and return activated sludge lines were initially inseparable, a method was devised to measure flow rates, explained in Appendix C.

Referring to Figure 7, the only streams directly known in the mainstream system are the secondary effluent and the filter backwash. The waste sludge and return sludge are known indirectly. The other streams must be obtained through hydraulic balances about the various unit operations and groups of unit operations.

Plant effluent: Hydraulic balance about gravity filters. PL. EFF. = (SEC. EFF.) - (FILTER B.W.)

Plant influent: Hydraulic balance about main stream system, assuming raw sludge stream is approximately equal to the recycle to mixing point 2. PL. INF = PL. EFF

Grit chamber influent: Hydraulic balance about mixing point 1. GR. CH. INF = (PL. INF.) + (RAW SL.)

Grit chamber effluent: Hydraulic balance about grit chamber, assuming grit volume is negligible. GR. CH. EFF. = GR. CH. INF.

Primary influent: Hydraulic balance about primary settler. PRI INF = (GR. CH. EFF) + (WAS) + (FILTER B.W.)

Primary effluent: Hydraulic balance about primary settler. PRI EFF = (PRI INF) - (RAW SL.)

Aeration influent: Hydraulic balance about mixing point 3. AER INF = (PRI EFF) + (RAS)

Aeration effluent: Hydraulic balance about aerators. AER. EFF = (AER INF) - (WAS - R).

The simplified sequential equalities above are expressed in terms of known quantities only. Table 25 summarizes flow calculations.

In contrast to mainstream operations, most flows in the sludge stream are directly measured. Raw sludge and vacuum filter-feed flow rates are measured by stroke counters on respective piston pumps (the volume of one stroke is 2.9 ft^3). The Zimpro feed and oxidized sludge flow streams are measured automatically by the Zimpro system. The volume of supernatant from the raw sludge holding tank was calcuated, knowing the diameter of tanks and levels of floating covers before and after supernating (1 in = 3,540 gal). The volume of filter cake produced was obtained from invoices by Caldwell Gravel Sales, Inc., a private contractor who hauls away the sludge cake. The weight of filter cake on the truck is on a wet-weight basis, and thus any attempt to calculate a mass flow rate of heavy metals must utilize a concentration expressed on a wet-weight basis. The Zimpro supernatant was initially measured with a V-notch weir constructed in the overflow sump adjacent to the Zimpro thickener. About two-thirds of the way through the project, the weir was removed by treatment plant personnel because it was causing a buildup of solids in the sump and effluent weir within the thickener. After that time, flow was estimated by a hydraulic balance on the Zimpro thickener, taking into account the discontinuous nature of the influent oxidized sludge stream and effluent vacuum filter-feed stream. The flow rate of the filtrate was estimated by a water balance around the vacuum filters. The mass of solids in these sludges was considered, explained more fully in Appendix C.

The Zimpro bypass stream was pumped by the same pumps used for the vacuum filter-feed stream, so its flow rate was measured by the stroke counter on those pumps. The lagoon feed stream was also pumped by those pumps, so its flow rate was measured in an analogous manner. The volume of grit produced was estimated by multiplying the number of times the grit truck was dumped by the volume it carried. Plant personnel estimated about 20 ft^3/truck, which agrees with the estimate of a typical conical pile of grit three feet high and five feet in diameter measured during the study.

The volumes of the two accumulations were also determined. The raw sludge holding tanks were equipped with floating covers, and the initial and final depths of sludge were used to calculate the net accumulation. The volume of accumulation in the Zimpro thickener was the volume of the thickener, since it was empty at the beginning and completely full at the end of the 60-day period. Table 26 summarizes this information.

Sampling Logistics

It became necessary to establish a routine to collect, transport, and analyze the large number of samples. First, the frequency of sampling necessary to establish a good mass balance was determined. For mainstream operations, this was determined by a trade-off between accuracy of the mass balance (better as more samples were collected) versus the time involved in collecting and analyzing (better as fewer samples were collected). Initially

TABLE 25. FLOW CALCULATION FORMULAS FOR MAIN STREAM SYSTEM

Stream	Flow Formula
PL. INF.	(SEC. EFF.) - (FILTER B.W.)
GR. CH. INF.	(SEC. EFF.) - (FILTER B.W.) + (RAW SL.)
GR. CH. EFF.	(SEC. EFF.) - (FILTER B.W.) + (RAW SL.)
PRI. INF.	(SEC. EFF.) + (WAS) + (RAW SL.)
PRI. EFF.	(SEC. EFF.) + (WAS)
AER. INF.	(SEC. EFF.) + (WAS) + (RAS)
AER. EFF.	(SEC. EFF.) + (RAS)
SEC. EFF.	SEC. EFF., Parshall Flume
PLANT EFF.	(SEC. EFF.) - (FILTER B.W.)
WAS	WAS, as per Appendix C
RAS	RAS, as per appendix C
FILTER B.W.	FILTER B.W., Totalizer
RAW SL.	RAW SL., Stroke Counter on Piston Pump
GRIT	GRIT, i.e., 20 ft^3/truckload

TABLE 26. FLOW CALCULATION FORMULAS FOR SLUDGE STREAM SYSTEM

Stream	Flow Formula
RAW SLUDGE	2.9 x (STROKES ON PISTON PUMP)
ZIM. FEED	Directly from Zimpro System
O_2 SLUDGE	Directly from Zimpro System
V. F. FEED	2.9 x (STROKES ON PISTON PUMP)
CAKE	From Innvoices of Sludge Hauler
SUP.	(3540 gal.) x (in. of Supernatant)
ZIM. SUP.	$Q = 2.5H^{2.5}$ for weir (Q in cfs, H in ft.)
	(O_2 SLUDGE) - (V. F. FEED)
FILTRATE	As per Appendix C
ZIM. BY-PASS	2.9 x (STROKES ON PISTON PUMP)
LAGOON FEED	2.9 x (STROKES ON PISTON PUMP)

there was a two-hour sampling frequency, but it was unworkable, with not enough time allowed to analyze samples and too much time taken by plant personnel. Thus, after day 5 the sampling interval was increased to four hours, cutting the time spent sampling in half and allowing twice as long with analysis. An intermediate calculation of mass balance progress was done on day 18 and showed no inaccuracy compared to one done after day 6. The four-hour sampling time continued for the project duration.

As explained previously, the sludge handling system was sampled every four hours when components were operational in order to conform to the project's activity. It should be noted that raw sludge was sampled once for each primary from which sludge was pumped and the supernatant once each time the operation was performed. The filter backwash was sampled every time a filter backwashed. An attempt was made to sample the grit daily, but only 11 samples were collected.

The sample bottles were washed, acid-soaked, rinsed, and air-dried before each use. All bottles were labeled in the lab with the sampling location for each use. Intermittent stream-sampling bottles were then bagged by stream and later placed at a convenient pit to be filled by plant operators. The nine mainstream bottles were labeled and bagged in a set for each sample. These bags were dropped off at a central plant location, the Zimpro service building basement, where operators did the sampling. The full bottles were put in a large plastic garbage can which was brought to Purdue about every other day. Bottles used for the intermittent streams were also placed in the garbage can. The person collecting each sample wrote the date and the time on the label with a waterproof marker.

At Purdue, the bottles were sorted and a log of the samples kept. When flow data were available, generally after about a one- or two-day lag, samples were composited for analysis and the bottles emptied and washed. There was about a ten-day turnaround for the 1,000 sampling bottles used in the study.

Finally, the route taken by plant personnel for collecting the nine mainstream processes had to be determined. Consulting with plant management, a route was developed which minimized the distance and time spent sampling, shown in Figure 9. All operators were familiarized with the route and had no difficulty during the study. The same route was used for sampling the primary influent.

Setting up a sampling program of this magnitude is a complex undertaking. Careful attention must be paid to detail, particularly to obtain a truly representative sample without undue inconvenience to people involved.

RESULTS

As stated previously, this field investigation at the Kokomo plant had two purposes: First, to determine a complete mass balance of five selected heavy metals (cadmium, chromium, copper, nickel, and zinc) and a shorter-term mass balance for iron and lead; and second, to actually complete such a sampling program at the Kokomo treatment plant.

Flow Rates

Mass balance comprises two elements: metal concentrations and measured flow rates. Average daily flow rates during the 60-day period are shown in Figure 10. In some instances, three figures label one flow stream. Figures in parentheses refer to the average flow rate of that stream for the number of days that it was in use, and the other figure refers to the average flow of that stream on a 60-day basis. Thus the total flow of that stream is presented and meaningful comparisons can be made between streams that were in use for different numbers of days. Values are also associated with the two accumulation terms. Accumulation in the raw sludge holding tank is actually negative; that is, there was a greater volume at the start of the project than at its completion. The direction of the arrow labeling the stream indicates this. It is shown as an influent stream, since the indicated volume was introduced to the system during the study. The accumulation in the Zimpro thickener is positive. This is indicated by the arrow labeling the stream as one of the effluents from the system because the positive accumulation can be thought of as being removed from the system as a whole to a fictional storage tank.

Table 27 summarizes recovery of the hydraulic balance. This can be measured in two ways: percentage of difference between total influent and total effluent quantities or pecentage of total influent accounted for in

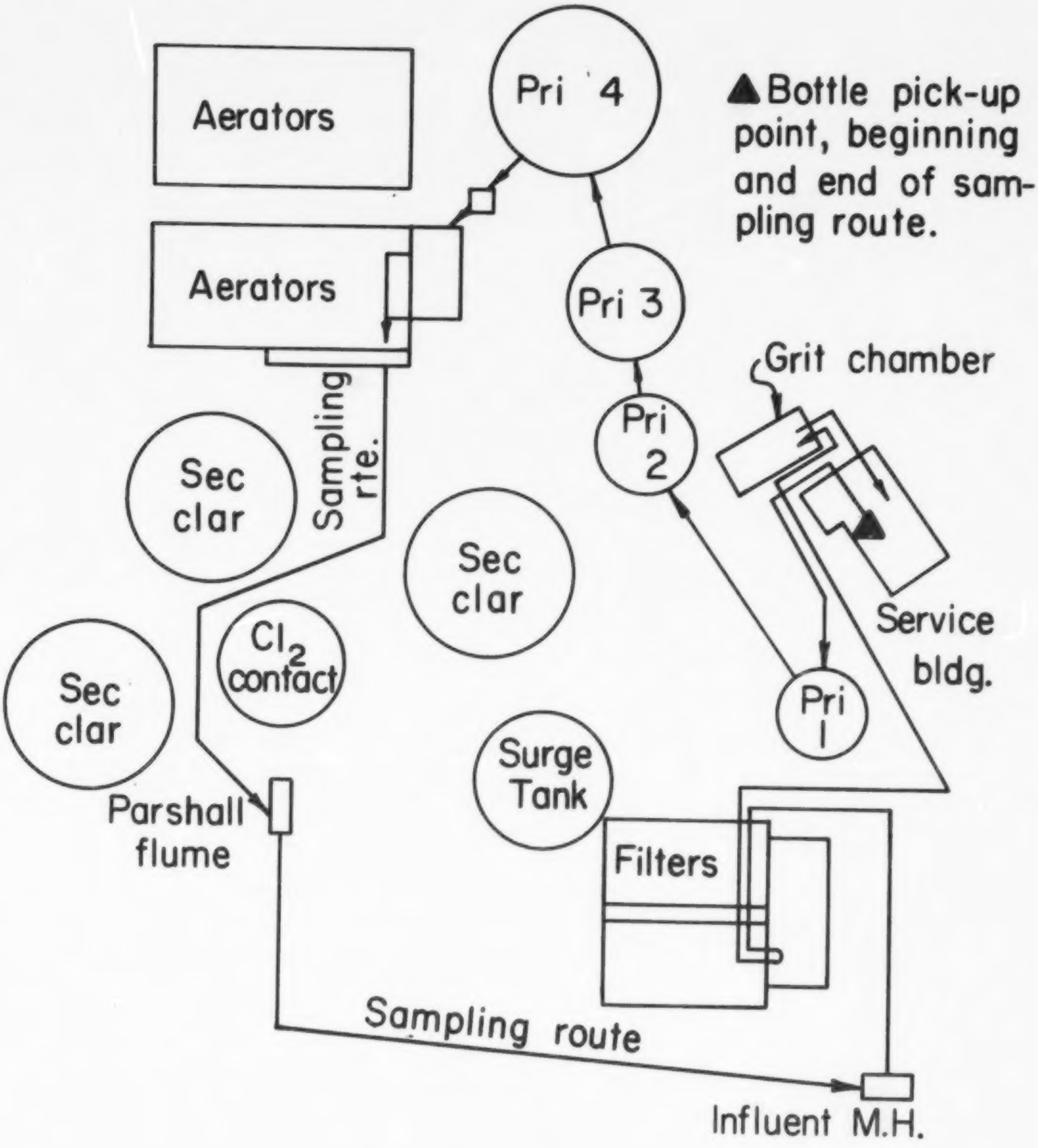
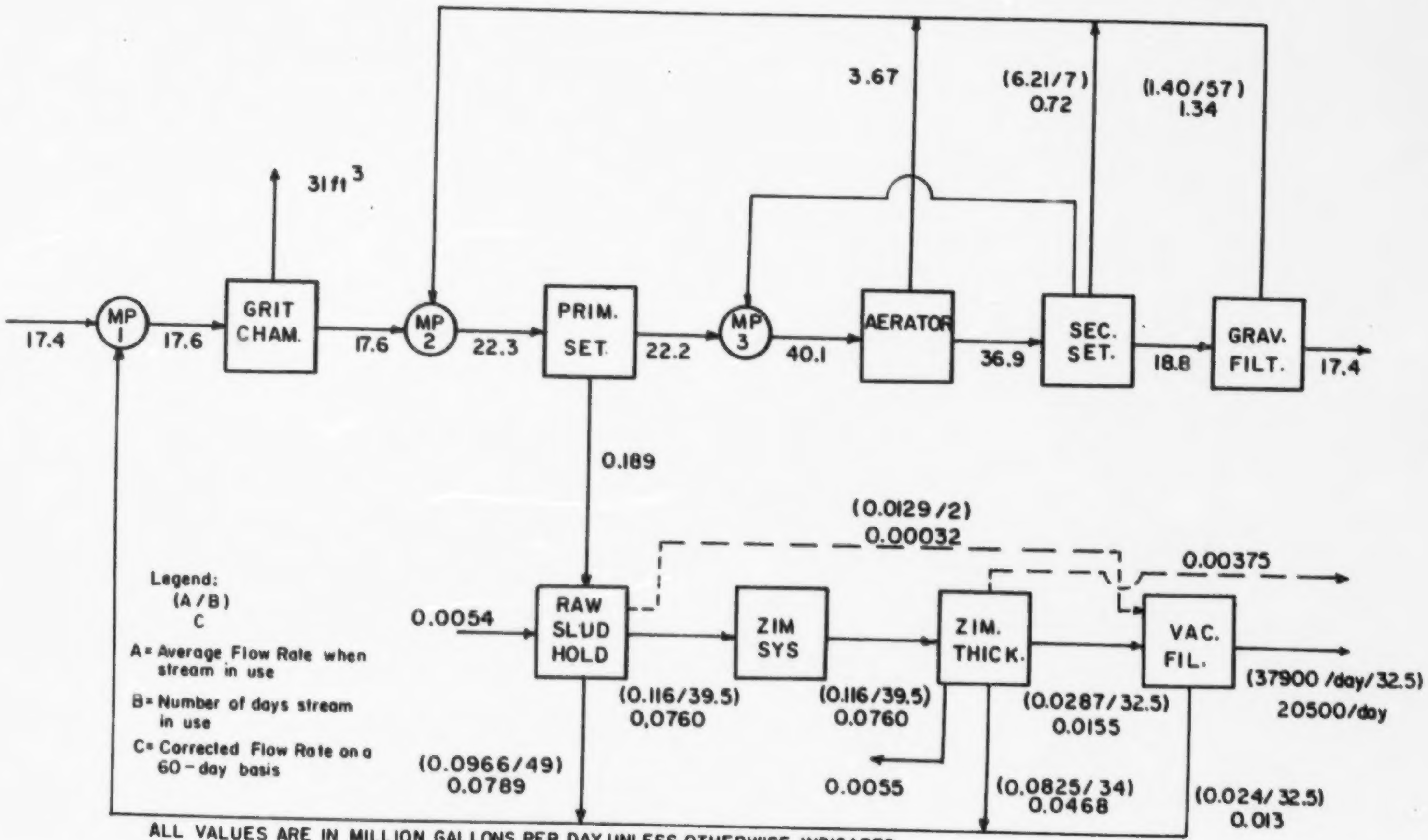

Aerators
Pri 4
▲Bottle pick-up point, beginning and end of sampling route.
Aerators
Pri 3
Grit chamber
Pri 2
Sampling rte.
Sec clar
Sec clar
Service bldg.
Cl_2 contact
Sec clar
Pri 1
Surge Tank
Parshall flume
Filters
Sampling route
Influent M.H.

Figure 9. Plant personnel sampling route.


17.4
MP 1
17.6
GRIT CHAM.
31 ft^3
17.6
MP 2
22.3
PRIM. SET
22.2
MP 3
40.1
AERATOR
36.9
SEC. SET.
18.8
GRAV. FILT.
17.4
3.67
(6.21/7)
0.72
(1.40/57)
1.34
0.189
Legend:
(A/B)
C
A = Average Flow Rate when stream in use
B = Number of days stream in use
C = Corrected Flow Rate on a 60-day basis
0.0054
RAW SLUD HOLD
(0.0129/2)
0.00032
ZIM SYS
ZIM. THICK.
0.00375
VAC. FIL.
(0.116/39.5)
0,0760
(0.116/39.5)
0.0760
(0.0287/32.5)
0.0155
(37900 /day/32.5)
20500/day
(0.0966/49)
0.0789
0.0055
(0.0825/34)
0.0468
(0.024/32.5)
0.013

ALL VALUES ARE IN MILLION GALLONS PER DAY UNLESS OTHERWISE INDICATED

Figure 10. Hydraulic balance.

TABLE 27. SUMMARY OF HYDRAULIC BALANCES

Operation	Influent Total Flow (MGD)	Effluent Total Flow (MGD)	% Recovery
MP 1	17.5	17.6	101
Grit Chamber	17.6	17.6	100
MP 2	23.3	22.3	95.7
Primary Settler	23.3	22.4	100
MP 3	39.9	40.1	101
Aerators	40.1	40.6	101
Secondary Settlers	36.9	37.2	101
Gravity Filters	18.8	18.7	99.7
Raw Sludge Holding Tank	0.194	0.156	80.3
Zimpro System	0.076	0.076	100
Zimpro Thickener	0.076	0.0716	94.1
Vacuum Filters	0.0158	0.0145	91.6

total effluent. The two methods are essentially equivalent, but the latter method was chosen and is termed "percent recovery." Table 27 shows that the mainstream operations have very good hydraulic balances and that the sludge stream operations are somewhat poorer.

Metal Concentrations

The second important component of mass balance is the concentration of heavy metal at various points within the treatment plant. Concentration is also important because it must be reduced to an acceptable level for discharge and it limits the land application rate of the sludge.

Tables 28 through 38 show concentrations of each metal at various points within the treatment plant. Only major streams are identified; the main streams are listed in Table 39. In addition to data for each unit operation of the plant, there are data for the plant as a whole and for each of the two components of the activated sludge system. Figures 11 through 17 are specific for each metal and show its concentration profile through the plant. The tables show the percent removal or the concentration, or both, of each metal.

TABLE 28. CONCENTRATION OF HEAVY METALS AROUND THE ENTIRE TREATMENT PLANT

	Concentration (mg/l)				
	Cd	Cr	Cu	Ni	Zn
Plant Inf. (Avg.)	0.0328	0.786	0.168	0.115	2.07
(Range)	0.00192- 0.0929	0.0267- 5.33	0.0558- 0.785	0.0107- 0.485	0.379- 5.52
Plant eff. (Avg.)	0.00631	0.0167	0.0252	0.0812	0.233
(Range)	0.0005- 0.0770	0.00391- 0.0727	0.00966- 0.0754	0.0303- 0.177	0.0721- 1.05
Sludge Cake[1] (Avg.)	377	1060	1790	533	13600
(Range)	165- 600	518- 4250	702- 6650	215- 968	4820- 17400
Percent Removal	80.8	97.9	85.0	29.4	88.7

	Concentration (mg/l)		
	Fe	Pb	SS
Plant Inf. (Avg.)	17.3	0.0507	151
Plant Eff. (Avg.)	0.335	0.00255	7.8
Sludge Cake[1] (Avg.)	71900	94.0	394000
Percent Removal	98.1	95.0	94.8

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[1] Sludge Cake concentration expressed in terms of mg/kg on a dry weight basis.

TABLE 29. CONCENTRATION OF HEAVY METALS AROUND GRIT CHAMBER

	Concentration (mg/l)				
	Cd	Cr	Cu	Ni	Zn
Grit Chamber Inf. (Avg.)	0.177	0.864	0.841	0.437	5.60
(Range)	0.0135-0.748	0.175-2.85	0.111-4.25	0.0660-5.49	1.16-1.21
Grit Chamber Eff. (Avg.)	0.177	0.931	0.705	0.471	5.42
(Range)	0.130-0.786	0.200-1.78	0.0988-3.20	0.0528-8.18	1.27-27.4
Grit[1] (Avg.)	124	344	1080	465	4610
Percent Removal	0.0	-7.8	16.2	-7.8	3.2

	Concentration (mg/l)		
	Fe	Pb	SS
Grit Chamber Inf. (Avg.)	91.4	0.282	-----
Grit Chamber Eff. (Avg.)	91.7	0.261	451
Grit[1]	175	1.55	-----
Percent Removal	-0.3	7.4	-----

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[1] Grit concentration expressed in terms of mg/kg on a dry weight basis.

TABLE 30. CONCENTRATION OF HEAVY METALS AROUND PRIMARIES

	Concentration (mg/l)				
	Cd	Cr	Cu	Ni	Zn
Pri. Inf. (Avg.)	0.425	2.19	2.18	1.20	15.8
(Range)	0.0793- 1.06	0.430- 5.86	0.408- 6.35	0.286- 3.64	2.81- 44.3
Pri. Eff. (Avg.)	0.251	1.33	1.15	0.615	8.42
(Range)	0.0397- 0.772	0.181- 3.59	0.124- 3.83	0.0478- 2.38	1.04- 28.3
Raw Sludge (Avg.)	33.8	102	143	65.8	965
(Range)	10.2- 57.3	29.8- 171	61.5- 314	18.7- 368	366- 2360
Percent Removal	40.9	39.3	47.2	48.8	46.7
Concentration Factor	138	119	139	112	131

	Concentration (mg/l)		
	Fe	Pb	SS
Pri. Inf. (Avg.)	156	0.684	----
Pri. Eff. (Avg.)	50.1	0.125	483
Raw Sludge (Avg.)	13600	30.7	----
Percent Removal	67.9	81.7	----
Concentration Factor	128	54.9	----

TABLE 31. CONCENTRATION OF HEAVY METALS AROUND AERATORS

	Concentration (mg/l)							
	Cd	Cr	Cu	Ni	Zn	Fe	Pb	SS
Aer. Inf. (Avg.)	1.36	7.17	5.79	2.76	46.4	468	1.23	4760
Aer. Eff. (Avg.)	1.35	7.16	5.79	2.75	46.3	518	1.22	4760
WAS-R (Avg.)	1.85	8.06	8.29	3.92	67.5	570	1.21	4760

TABLE 32. CONCENTRATION OF HEAVY METALS AROUND SECONDARIES

	Concentration (mg/l)				
	Cd	Cr	Cu	Ni	Zn
Aer. Eff. (Avg.)	1.35	7.16	5.79	2.75	46.3
(Range)	0.579- 2.50	2.88- 12.6	3.02- 10.2	0.432- 6.36	14.1- 109
Sec. Eff. (Avg.)	0.0124	0.0773	0.0574	0.0988	0.488
(Range)	0.00119- 0.121	0.0153- 0.863	0.0103- 0.543	0.0419- 0.360	0.133- 3.79
RAS (Avg.)	2.50	11.0	11.6	4.74	86.3
(Range)	0.605- 6.95	4.27- 33.1	3.89- 27.4	0.742- 15.6	17.7- 224

	Concentration (mg/l)		
	Fe	Pb	SS
Aer. Eff. (Avg.)	518	1.22	4760
Sec. Eff. (Avg.)	1.75	0.00525	26.3
RAS (Avg.)	837	1.95	8720

TABLE 33. CONCENTRATION OF HEAVY METALS AROUND ACTIVATED SLUDGE SYSTEM

	Concentration (mg/l)				
	Cd	Cr	Cu	Ni	Zn
Pri. Eff. (Avg.)	0.251	1.33	1.15	0.615	8.42
(Range)	0.0397-0.772	0.181-3.59	0.124-3.83	0.0478-2.38	1.04-28.3
Sec. Eff. (Avg.)	0.0124	0.0773	0.0574	0.0988	0.488
(Range)	0.00119-0.121	0.0153-00.863	0.0103-0.543	0.0419-0.360	0.133-3.79
WAS-R (Avg.)	1.85	8.06	8.29	3.92	67.5
(Range)	0.385-3.93	2.01-15.0	1.42-18.3	0.440-7.55	18.7-1.26
Percent Removal	95.1	94.2	95.0	83.9	94.2
Concentration Factor	7.75	6.43	7.59	7.59	8.51

	Concentration (mg/l)		
	Fe	Pb	SS
Pri. Eff. (Avg.)	50.1	0.125	483
Sec. Eff. (Avg.)	1.75	0.00525	26.3
WAS-R (Avg.)	570	1.21	4760
Percent Removal	96.5	95.8	94.6
Concentration Factor	11.8	10.1	10.4

TABLE 34. CONCENTRATION OF HEAVY METALS AROUND GRAVITY FILTERS

	Concentration (mg/l)				
	Cd	Cr	Cu	Ni	Zn
Sec. Eff. (Avg.)	0.0124	0.0773	0.0574	0.0988	0.488
(Range)	0.00119-0.121	0.0153-0.863	0.0103-0.543	0.0419-0.360	0.133-3.79
Plant Eff. (Avg.)	0.00631	0.0167	0.0252	0.0812	0.233
(Range)	0.0005 0.0770	0.00391-0.0727	0.00966-0.0754	0.0303-0.177	0.0721-1.05
Filter B.W. (Avg.)	.259	1.03	0.460	0.441	0.410
(Range)	0.00192-0.516	0.0493-3.90	0.00557-2.18	.0425-1.58	0.215-17.6
Percent Removal	49.1	78.4	56.1	17.8	52.3

	Concentration (mg/l)		
	Fe	Pb	SS
Sec. Eff. (Avg.)	1.75	0.00525	26.3
Plant Eff. (Avg.)	0.335	0.00255	7.8
Filter B.W. (Avg.)	35.4	0.0803	440
Percent Removal	80.9	51.4	70.3

TABLE 35. CONCENTRATION OF HEAVY METALS AROUND RAW SLUDGE HOLDING TANK

	Concentration (mg/l)							
	Cd	Cr	Cu	Ni	Zn	Fe	Pb	TS
Raw Sludge (Avg.)	24.0	102	143	56.8	965	13600	30.7	-----
Zim. Feed (Avg.)	21.0	71.5	99.9	39.9	745	9630	23.1	68600
Sup. (Avg.)	28.4	85.	140	53.0	889	15100	36.9	3000

TABLE 36. CONCENTRATION OF HEAVY METALS AROUND ZIMPRO REACTOR

	Concentration (mg/l)							
	Cd	Cr	Cu	Ni	Zn	Fe	Pb	TS
Zim. Feed (Avg.)	21.0	71.5	99.9	39.9	745	9630	231	68600
O_2 Sludge (Avg.)	19.9	68.9	67.2	38.1	720	9910	24.0	61000

TABLE 37. CONCENTRATION OF HEAVY METALS AROUND ZIMPRO THICKENER

	Concentration (mg/l)							
	Cd	Cr	Cu	Ni	Zn	Fe	Pb	SS
O_2 Sludge (Avg.)	19.9	68.9	67.2	38.1	720	9910	24.0	61000
V.F. Feed (Avg.)	54.3	200	244	91.1	1730	20400	51.4	159000
Zim. Sup. (Avg.)	1.18	4.42	5.24	2.87	35.7	181	0.469	----
Concentration Factor	2.73	2.90	3.63	2.39	2.40	206	2.14	2.61

TABLE 38. CONCENTRATION OF HEAVY METALS AROUND VACUUM FILTERS

	Concentration (mg/l)							
	Cd	Cr	Cu	Ni	Zn	Fe	Pb	TS
V.F. Feed (Avg.)	54.3	200	244	91.1	1730	20400	51.4	159,000
Filter Cake[1] (Avg.)	377	1060	1790	533	13600	71900	94.0	394,000
Filtrate (Avg.)	25.6	72.8	146	66.4	1014	21900	33.0	56200
Concentration Factor	6.94	5.30	7.3	5.85	7.86	3.52	1.83	2.48

[1] Filter Cake concentration expressed in terms of mg/kg on a dry weight basis.

TABLE 39. CONCENTRATIONS OF HEAVY METALS IN MINOR PLANT STREAMS

	Concentration (mg/l)						
Stream	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Primary Skimmings	0.350	1.42	3.27	1.33	7.70	—	—
Secondary Skimmings	0.0772	0.446	0.556	2.05	6.88	—	—
WAS-U	1.18	7.43	6.88	3.27	52.0	—	—
Zim. By-Pass	19.2	41.7	81.0	26.7	510	—	—
Lagoon Feed	54.3	200	244	91.1	1730	—	—
Raw Sludge Holding Tank-Accumulation	28.4	85.0	140	53.0	889	—	—
Zimpro Thickener-Accumulation	54.3	200	244	91.1	1730	—	—

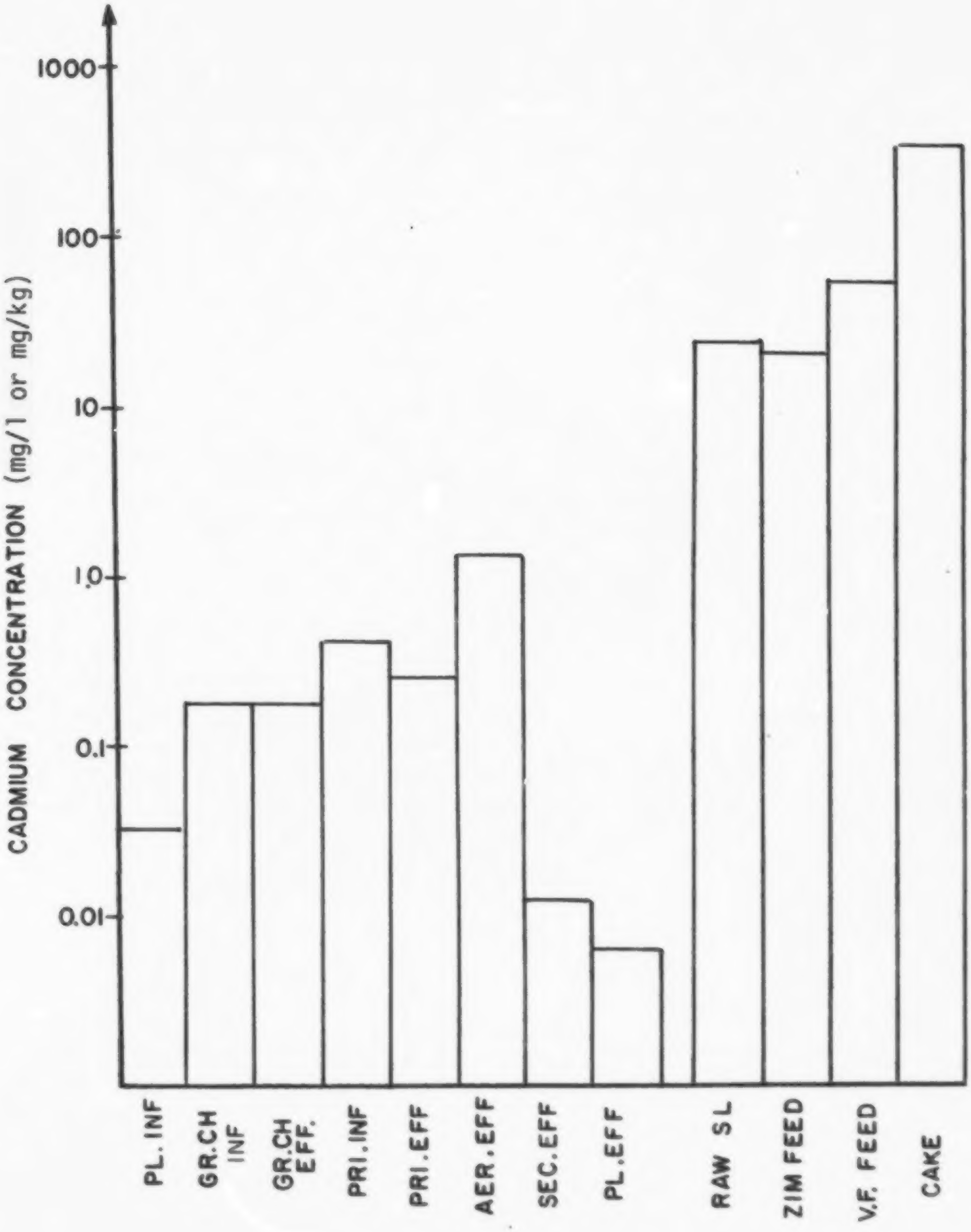


Figure 11. Cadmium profile.

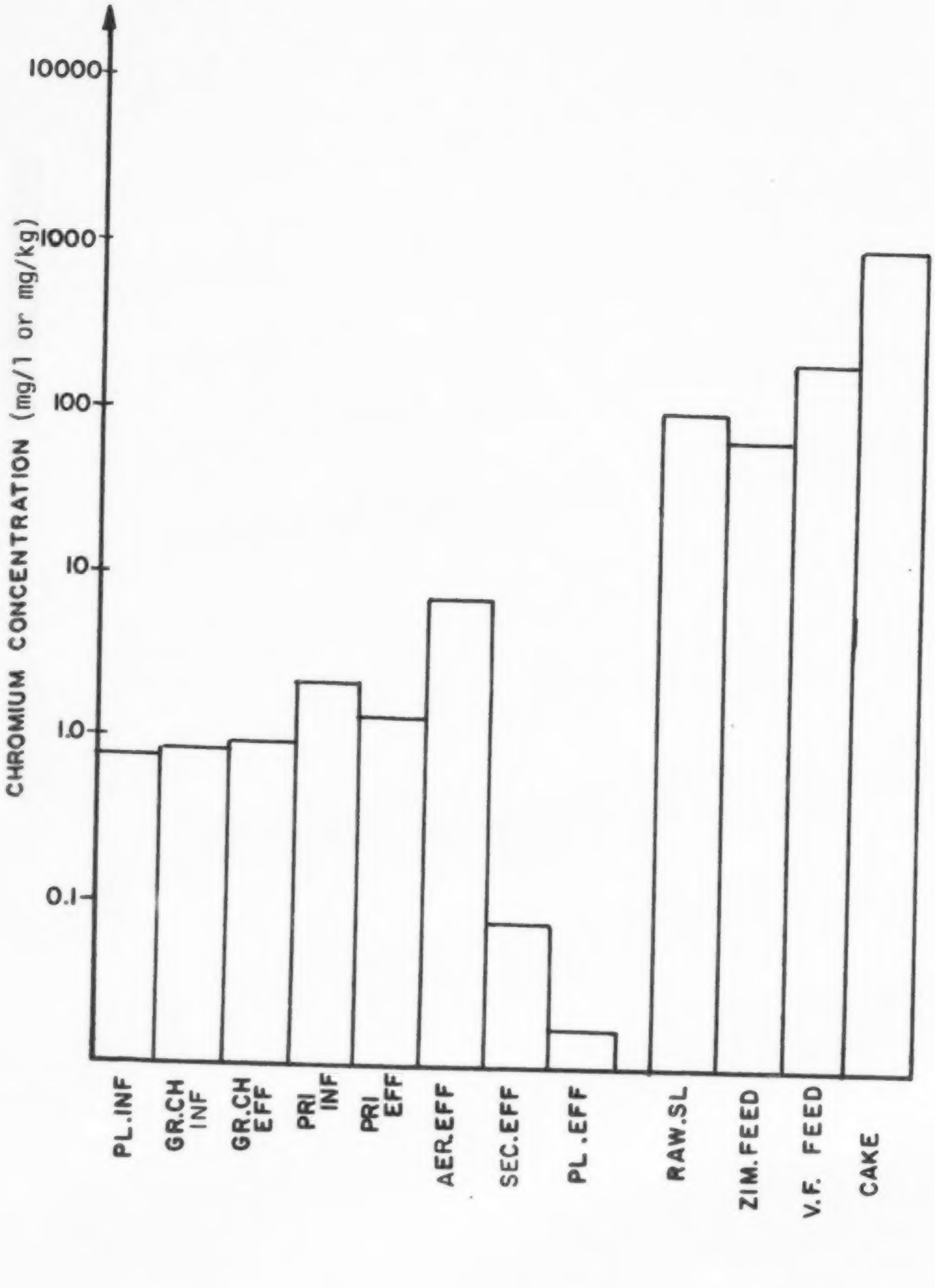


Figure 12. Chromium profile.

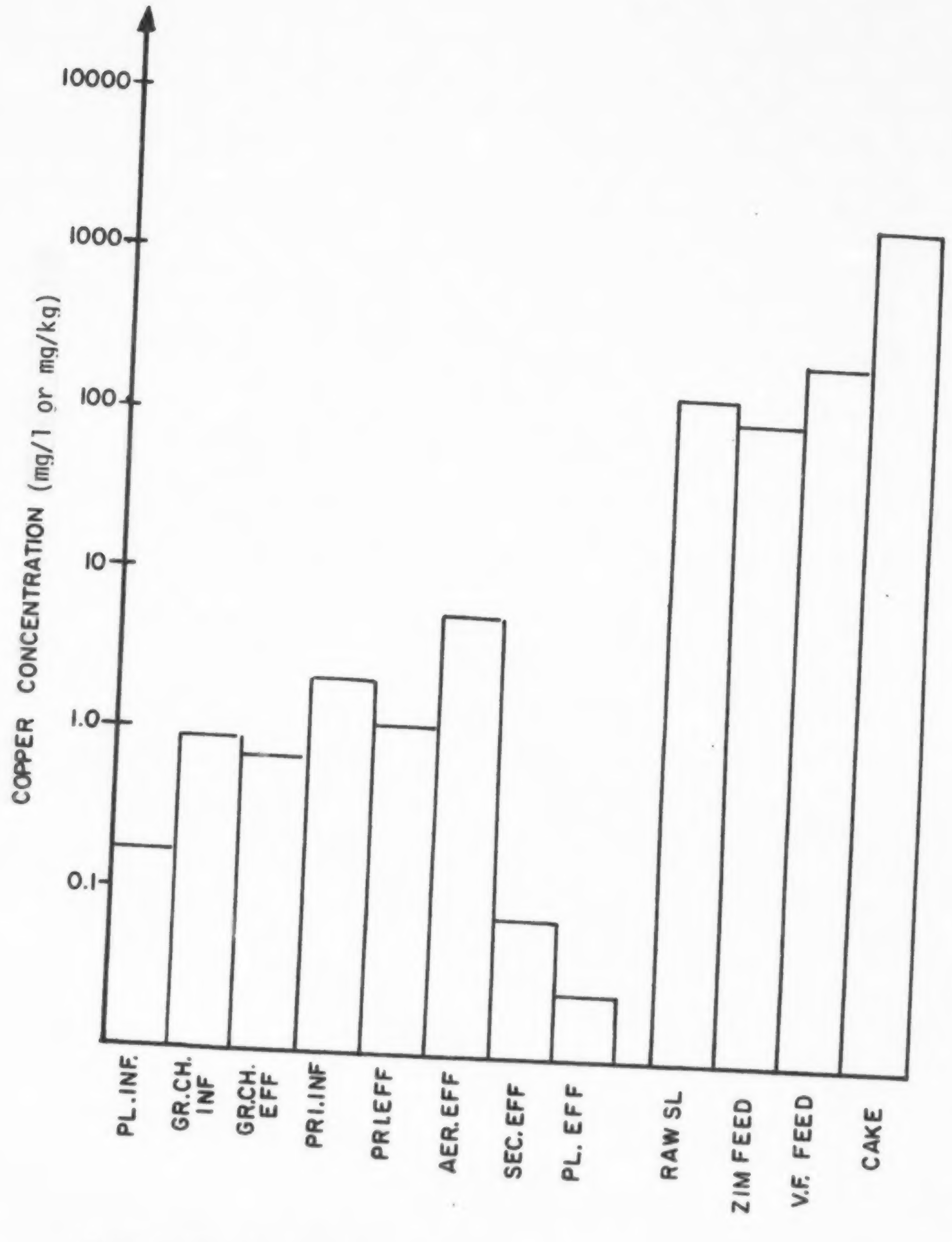


Figure 13. Profile of copper concentrations in various treatment plant streams.

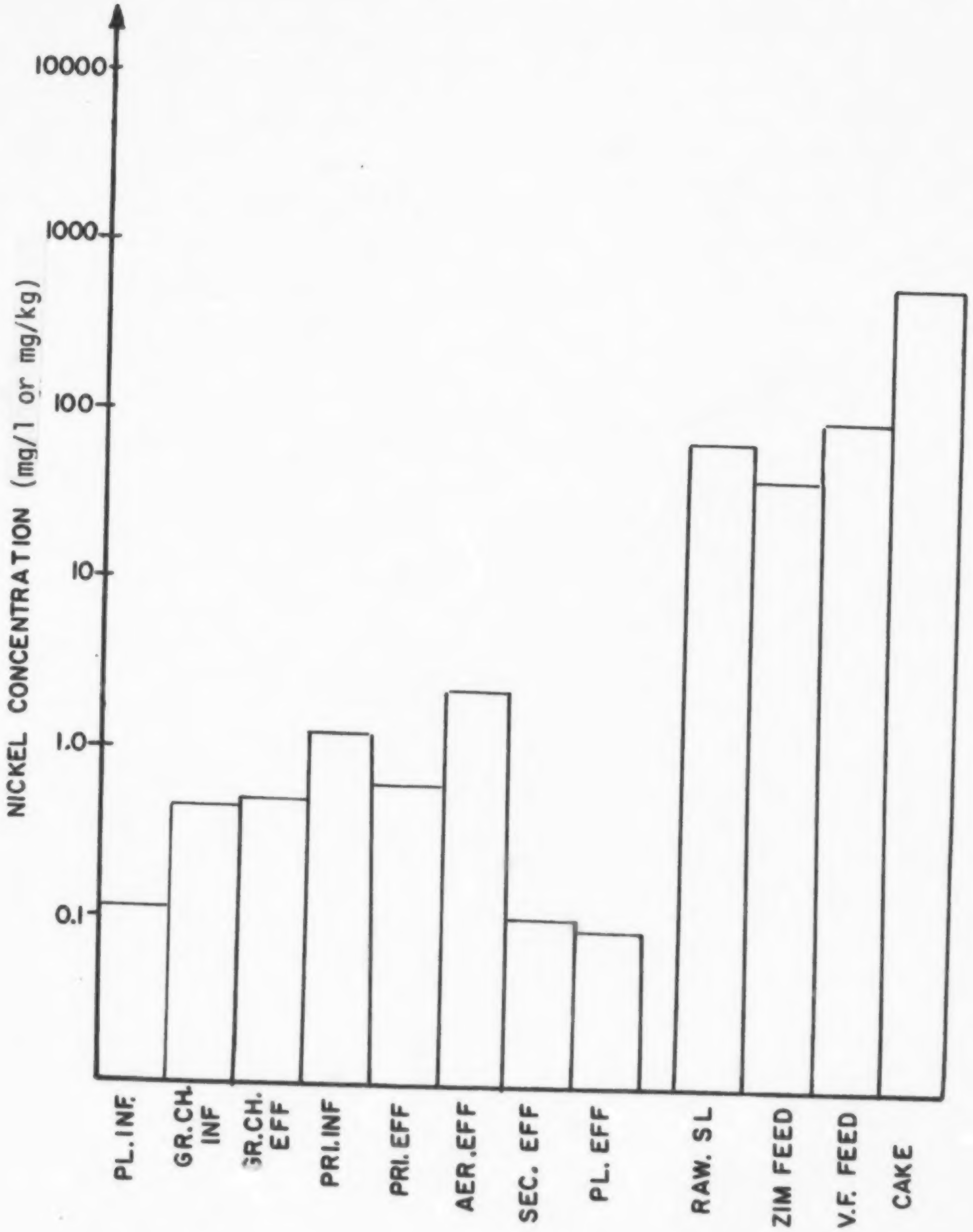


Figure 14. Nickel profile.

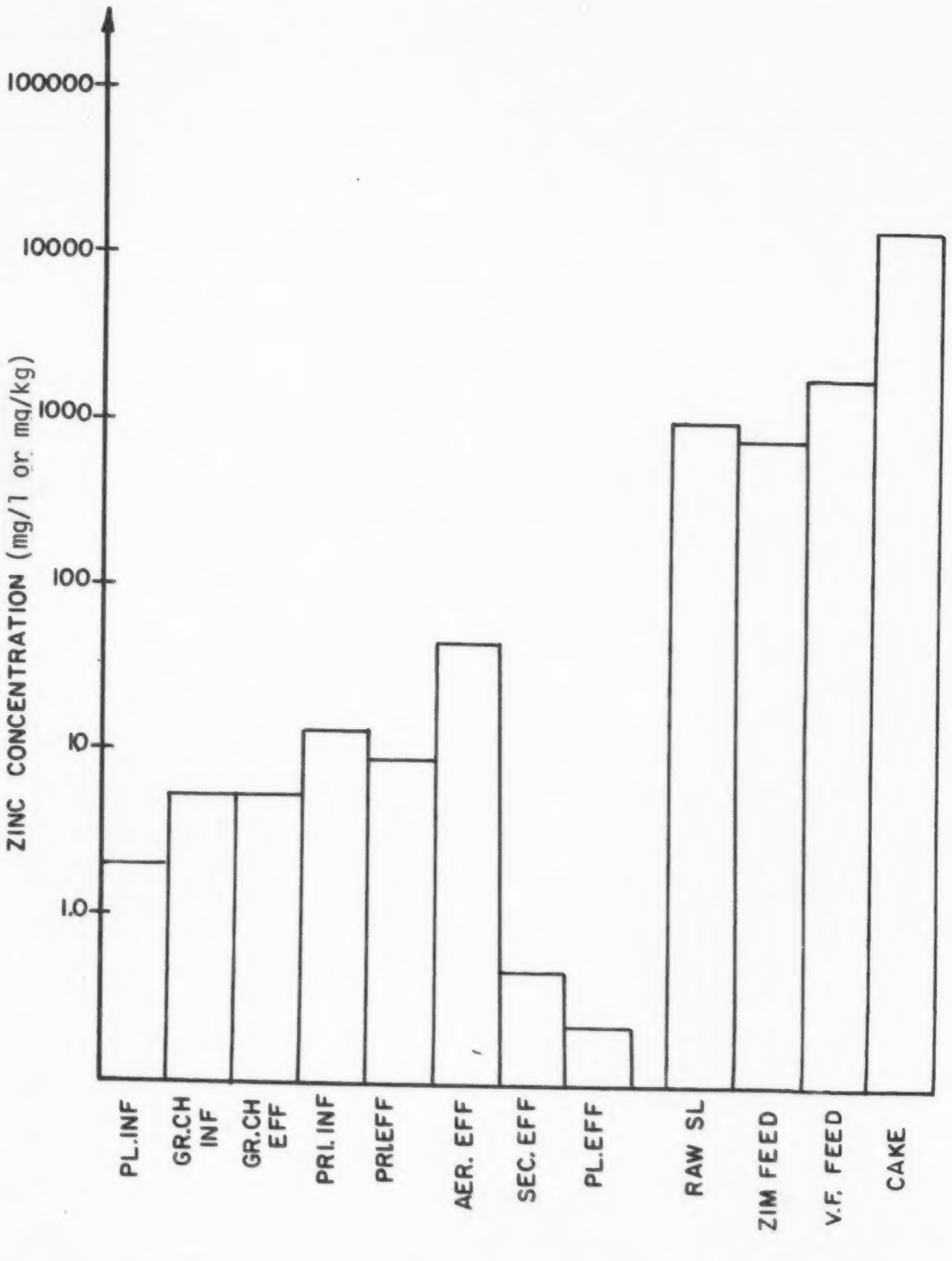


Figure 15. Zinc profile.

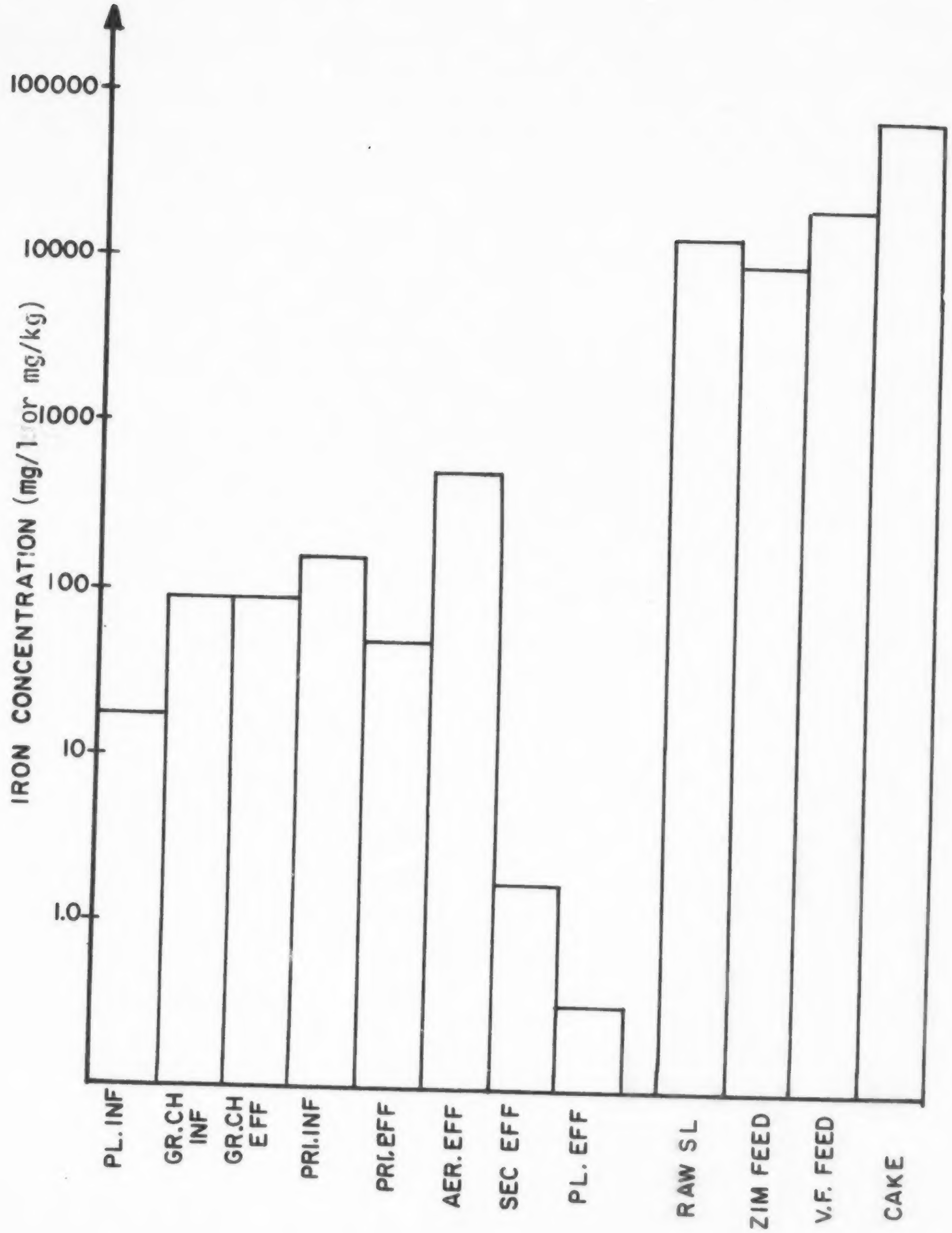


Figure 16. Iron profile.

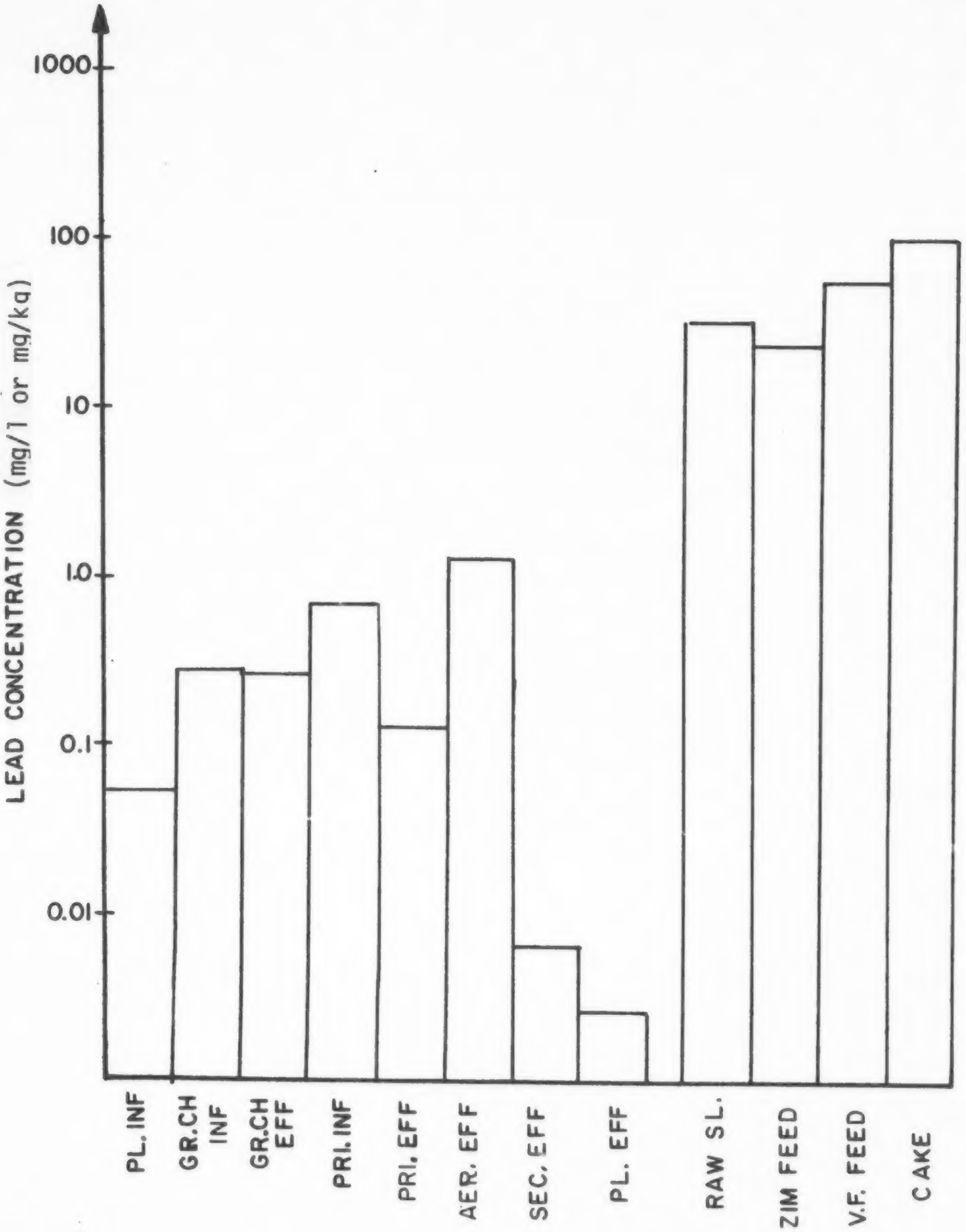


Figure 17. Lead profile.

The concentration factor is defined by Olthor (1978) as the sludge concentration divided by the differences between the influent and effluent metal concentrations, but for sludge handling streams, it is merely the effluent divided by the influent metal concentrations.

Examination of data in Tables 28 to 38 and Figures 11 and 17 reveals several important points. The most striking feature is the similar behavior of all the metals except nickel. All except nickel are removed to a very large extent in the mainstream operations and are concentrated in the filter cake. The percent removal calculated in the tables can be somewhat misleading. As used, they are defined to be the percent removal with respect to the influent and effluent of the process considered. This method of expressing removal efficiencies is necessary because of in-plant recirculation. For example, if the percent removal of primaries was calculated on the plant influent, a negative percent removal would result, which would give no useful information about that system's efficiency.

Table 29 shows that the grit chamber is largely ineffective for heavy metals removal, as would be expected. The negative removals measured for chromium, nickel, and iron are considered insignificant, in effect, zero. As seen, the concentrations of metals in grit is fairly high, necessitating some consideration of its ultimate disposal. The aerated grit chamber at Kokomo produces a grit that has a great deal of putrescible organic matter associated with it. This organic matter originates from recirculating three of the sludge streams to the wet well preceding the grit chamber. This matter raises the metal concentration of grit chamber influent and effluent over plant influent. It seems logical that eliminating this matter from the grit would reduce the metal levels and help the odor problem. Adjusting the air flow rate in the grit chamber might also help.

The removal efficiency of the primaries for the seven metals is approximately 50 percent, shown in Table 30. Iron and lead are somewhat higher and chromium somewhat lower. The large iron removal may be from its propensity to act as a coagulant, especially realizing that the Kokomo plant wastes its excess secondary sludge to the primaries and noting the high iron concentration with which it mixes, 91.7 mg/l, in the grit chamber effluent. The lead value is probably due to the low concentration of lead measured and the relative insensitivity of atomic absorption spectrophotometry to lead. The lower chromium removal may be due to the high solubility of chromium VI present in the influent. The concentration factor regarding sludge mirrors the trends of the percent of removals, however, the discrepancy in lead is opposite to that of the percent of removal, that is, if more lead were removed than the average, its concentration factor should be higher than the average. It is lower. This supports the reasoning of experimental error in determination of low lead values. Unfortunately, Kokomo does not report suspended solids of the true primary influent but actually of the grit chamber effluent, so no comparison could be made of heavy metals to suspended solids removal in the primaries.

Table 33 shows that the activated sludge system is the primary removal operation for heavy metals. The removal efficiencies of all the metals, excepting nickel, are about 95 percent. The lower nickel removal efficiency

(83.9 percent) is due to its inherent chemistry and has been observed by many others, as shown in the literature review. At this point, metal concentrations have decreased from the influent concentration to the plant. They have been concentrated by a factor of about 7 in the mixed liquor. The removal efficiency of the secondary clarifier is very high for suspended solids and metals, shown in Table 32. In fact, the removal efficiency of suspended solids mirrors that of heavy metals; however, no generalizations are possible due to different removal mechanisms for suspended solids and metals, for example, floc enmeshment versus adsorption onto the floc.

Gravity filters remove suspended solids. At Kokomo, filters remove 70.3 percent of the suspended solids but only about 50 percent of cadmium, copper, zinc, and lead. Chromium and iron are removed to about the same degree as suspended solids, while nickel is barely removed. Since some insoluble metal is removed by secondary clarifiers, influent to the filters should contain a higher proportion of soluble metal, and thus the filters should not be as effective for metal removal as for suspended solids removal. This is borne out by most of the metals, in particular nickel, but not for chromium and iron. This could possibly mean that the majority of the iron and chromium are present in insoluble form.

The sludge-handling stream increases metal concentration to that of filter cake. However, as shown in Table 35, no increase occurs through the raw sludge holding tank, in fact, metal concentration decreases. The reason may depend on the piping in the tanks which are old anaerobic digesters and therefore do not act as thickeners, since only minor modifications occurred in the changeover to holding tanks.

There is no concentration through the Zimpro reactors, shown in Table 36. This is expected, as well as the slight decrease in solids volatilized by the process. The concentration is effected by the thickener which results in a twofold or threefold concentration of all metals and solids, with a purely thickening phenomenon occurring. The Zimpro supernate also has low metal levels.

Metal concentration is continued by vacuum filters, this time with about a five to sevenfold increase. Solids do not quite mirror this increase because cake metal content is expressed on a dry solids basis, while the solids content of cake is on a wet-weight basis. Dividing the concentration factor for the solids by 0.40, about the average percentage of solids, increases it to 6.2, which is in the same range as the metals.

Tables 28 through 34 present ranges in metal concentrations, as well as averages. These are presented primarily for the sake of completeness and to demonstrate that the plant operated during periods of high and low metal loadings, and that the metal concentration at points within the plant is not static but varies greatly.

Comparison of Table 28, the metal concentrations at Kokomo, with those of other cities in Table 7 shows that Kokomo has very high influent cadmium and iron concentrations, moderately high chromium and zinc concentrations, normal copper and nickel levels, and low lead levels. However, removal efficiencies of the Kokomo plant are, except for nickel, better than any of the other treatment plants of Table 8. Also effluent metal concentrations at Kokomo are slightly lower than most plants listed in Table 9. These facts substantiate hypotheses of heavy metal removal by insoluble iron oxides as one of the major removal mechanisms, as suggested in the literature review. Comparison of sludge data from Kokomo to that from other cities shows that Kokomo has high sludge metal concentrations and that, in particular, cadmium and zinc are very high.

The Mass Balance

The total poundage of a given metal which passes through any stream during the 60-day period is the product of the flow rate and concentration. Mass balances determined about each of the nine operations of Figure 7, as well as the three mixing points and plant, are shown in Tables 40 through 52, which should be used in conjunction with Figure 7. Percent of recovery is again used as a measure of mass balance and is the same concept used earlier for flow rates. Figures 18 through 24 are specific to each metal for the treatment plant and its operations. The mass balance data are complete for the five principal metals studied, but they only include mainstream operations for iron and lead because of the short sampling period of 11 days, which did not allow enough sampling for a meaningful evaluation. Table 53 summarizes the percent of recovery of each metal from each unit operation.

The usefulness of a mass balance is that it shows the fate of a particular metal as it moves through a system such as a treatment plant. The fraction of influent metal present in the sludge should be theoreticaly equal to the removal efficiency of a process for the metal. Table 54 contains results for the primary clarifiers and plant as a whole. The removal efficiency of the primaries is based on the primary influent; the filter cake is actually a sum of the lagoon feed plus the filter cake. The second purpose of a mass balance is to locate potential errors in analyses of metal concentration, or flow rates.

A comparison of Table 54 to Table 30 shows good agreement between removal percentages and the fraction of influent metal in the sludge for the primaries. Comparison of Table 54 with Table 28 does not show such good agreement for the plant as a whole because of errors in concentration or flow rates of the mass balance. Examination of Table 53 for the entire plant reveals that same data trend, as does Table 54. This indicates that cadmium, copper, and nickel values are realistic, since they do not greatly differ from the removal percentages in Table 28. The percent of zinc recovery is relatively low, indicating a possible error in measuring the zinc concentration of the filter cake. This is possible because of the great zinc concentrations measured which necessitated dilutions of up to 10,000:1 in some instances, thus greatly increasing the chance for experimental error. However, the percent of recovery of zinc about the vacuum filters is close to 100 percent, seemingly invalidating the previous argument. A closer data examination reveals a low (80.7) percent of recovery, indicating that the zinc concentration in the feed to the vacuum filter is also wrong, possibly for the same reasons. In summary, the actual zinc concentration in the vacuum filter feed and in the filter cake is low due to experimental error.

TABLE 40. MASS BALANCE AROUND THE PLANT AS A WHOLE

Streams	Pounds of Metal Cd	Cr	Cu	Ni	Zn	Fe	Pb
Plant Inf.	285	6848	1460	1003	18019	26442	77.8
Raw Sl. Hold. Tank Acc.	64.5	274	384	177	2591	680	1.7
TOTAL IN	350	7122	1844	1180	20610	27122	79.5
Plant Eff.	54.9	145	220	707	2026	515	3.9
Filter Cake	186	525	880	260	6691	6495	8.5
Lagoon Feed	102	283	459	171	3249	0	0
Zimpro Thickener Acc.	149	551	671	251	4756	0	0
Grit	4.3	11.9	37.3	16.1	160	1310	11.6
TOTAL OUT	496	1516	2267	1405	16882	8320	24.0
% Recovery	142.0	21.3	123.0	119.1	81.9	*	*

* Note: insufficient sampling period for balance.

TABLE 41. MASS BALANCE AROUND THE GRIT CHAMBER

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Gr. Ch. Inf.	1542	7530	7320	3804	48775	140220	432
TOTAL IN	1542	7530	53200	3804	48775	140220	432
Gr. Ch. Eff.	1540	8102	6139	4101	47255	140696	401
Grit	4.3	11.9	37.3	16.1	160	1310	11.6
TOTAL OUT	1544	8114	6176	4117	47415	142006	413
% Recovery	100.1	107.8	84.4	108.2	97.2	101.2	95.5

TABLE 42. MASS BALANCE AROUND THE PRIMARIES

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Pri. Inf.	4738	24482	24301	13422	175781	303440	1328
TOTAL IN	4738	24482	24301	13422	175781	303440	1328
Pri. Eff.	2785	14837	12735	6834	93571	96490	242
Raw Sl.	2272	9656	13561	6227	91310	234810	531
TOTAL OUT	5057	24493	26296	13061	184881	331300	773
% Recovery	106.7	100.0	108.2	97.3	105.2	109.2	58.2

TABLE 43. MASS BALANCE AROUND THE AERATORS

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Aer. Inf.	27279	143821	116139	55376	930542	1551900	4074
TOTAL IN	27279	143821	116139	55376	930542	1551900	4074
WAS-R	1736	10952	10130	4810	76651	183100	386
Aer. Eff.	25015	132215	106830	50772	854792	1397000	3668
TOTAL OUT	26751	143167	116960	55582	931443	1580100	4054
% Recovery	98.1	99.5	100.7	100.4	100.1	101.8	99.5

TABLE 44. MASS BALANCE AROUND THE SECONDARY CLARIFIERS

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Aer. Eff.	25015	132215	106830	50772	854792	1397000	3668
TOTAL IN	25015	132215	106830	50772	854792	1397000	3668
RAS	22118	97141	102643	42015	764275	1389000	3234
WAS-U	1656	3842	5091	2405	47306	-----	----
Sec. Eff.	117	727	540	929	4590	2839	8.5
TOTAL OUT	23891	101710	108274	45349	816171	1392000	3242
% Recovery	95.5	76.9	101.4	89.3	95.5	99.7	88.4

TABLE 45. MASS BALANCE AROUND THE GRAVITY FILTERS

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Sec. Eff.	117	727	540	929	4590	2839	8.5
TOTAL IN	117	727	540	929	4590	2839	8.5
Pl. Eff.	54.9	145	220	707	2026	515	3.9
Filter B.W.	59.4	690	308	295	2743	3060	7.0
TOTAL OUT	114	835	528	1002	4769	3575	10.9
% Recovery	97.7	114.9	97.8	107.9	103.9	125.9	128.2

TABLE 46. MASS BALANCE AROUND THE RAW SLUDGE HOLDING TANK

	Pounds of Metal				
Streams	Cd	Cr	Cu	Ni	Zn
Raw Sl.	2272	9656	13561	6227	91310
Raw Sl. Holding Tank Acc.	64.5	274	384	177	2591
TOTAL IN	2336	9930	13945	6404	93901
Zim. Feed	805	2742	3832	1529	28559
Zim. By-Pass	4.7	10.1	19.6	6.5	124
Sup.	1122	3356	5535	2092	35102
TOTAL OUT	1932	6108	9387	3628	63785
% Recovery	82.7	61.5	67.3	56.6	67.9

TABLE 47. MASS BALANCE AROUND ZIMPRO REACTORS

Streams	Pounds of Metal Cd	Cr	Cu	Ni	Zn
Zim. Feed	805	2742	3831	1532	28560
TOTAL IN	805	2742	3831	1532	28560
O_2 Sludge	767	2641	2576	1462	27598
TOTAL OUT	767	2641	2576	1462	27598
% Recovery	95.3	96.3	67.2	95.4	96.6

TABLE 48. MASS BALANCE AROUND THE ZIMPRO THICKENER

Streams	Pounds of Metal Cd	Cr	Cu	Ni	Zn
O_2 Sludge	767	2641	2576	1462	27598
TOTAL IN	767	2641	2576	1462	27598
V.F. Feed	422	1555	1894	708	13436
Zim. Sup.	27.5	103	123	67.2	835
Lagoon Feed	102	283	459	171	3249
Zim. Thickener Accumulation	149	551	671	251	4756
TOTAL OUT	700	2492	3147	1197	2276
% Recovery	91.3	94.4	122.2	81.9	80.7

TABLE 49. MASS BALANCE AROUND THE VACUUM FILTERS

	Pounds of Metal				
Streams	Cd	Cr	Cu	Ni	Zn
V. F. Feed	422	1555	1894	708	13436
Zim. By-Pass	4.7	10.1	19.6	6.5	125
TOTAL IN	427	1565	1914	714	13560
Filter Cake	186	525	880	261	6691
Filtrate	166	473	947	432	6596
TOTAL OUT	352	998	1827	693	13287
% Recovery	82.5	63.8	95.5	97.1	98.0

TABLE 50. MASS BALANCE AROUND MIXING POINT 1

	Pounds of Metal				
Streams	Cd	Cr	Cu	Ni	Zn
Pl. Inf.	285	6848	1460	1003	18019
Sup.	1122	3356	5535	2092	35102
Zim. Sup.	27.5	103	123	67.2	835
Filtrate	166	474	947	432	6596
TOTAL IN	1550	10781	8065	3594	60552
Gr. Ch. Inf.	1542	7530	7320	3804	48775
TOTAL OUT	1542	7530	73200	3804	48775
% Recovery	99.5	69.8	90.8	105.8	80.6

TABLE 51. MASS BALANCE AROUND MIXING POINT 2

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Gr. Ch. Eff.	1541	8102	6139	4101	47255	140696	401
WAS-R	1736	10952	10130	4810	76651	183100	386
WAS-U	1656	3842	5091	2405	47306	0.0	0.0
Filter B.W.	59.4	690	308	295	2743	3059	7.0
TOTAL IN	4992	23586	21668	11611	173955	326855	794
Pri. Inf.	4738	24482	24301	13421	175781	303440	401
TOTAL OUT	4738	24482	24301	13421	175781	303440	401
% Recovery	94.9	103.8	112.1	115.6	101.0	92.8	50.5

TABLE 52. MASS BALANCE AROUND MIXING POINT 3

	Pounds of Metal						
Streams	Cd	Cr	Cu	Ni	Zn	Fe	Pb
Pri. Eff.	2785	14837	12735	6834	93591	96490	24200
RAS	22118	997141	102643	42015	764275	1389356	3234
TOTAL IN	24903	111978	115378	48849	857866	1485846	3476
Aer. Inf.	27279	143821	116139	55376	930542	1551900	4074
TOTAL OUT	27279	143821	116139	55376	930542	1551900	4074
% Recovery	109.5	128.4	100.7	113.4	112.0	104.4	117.2

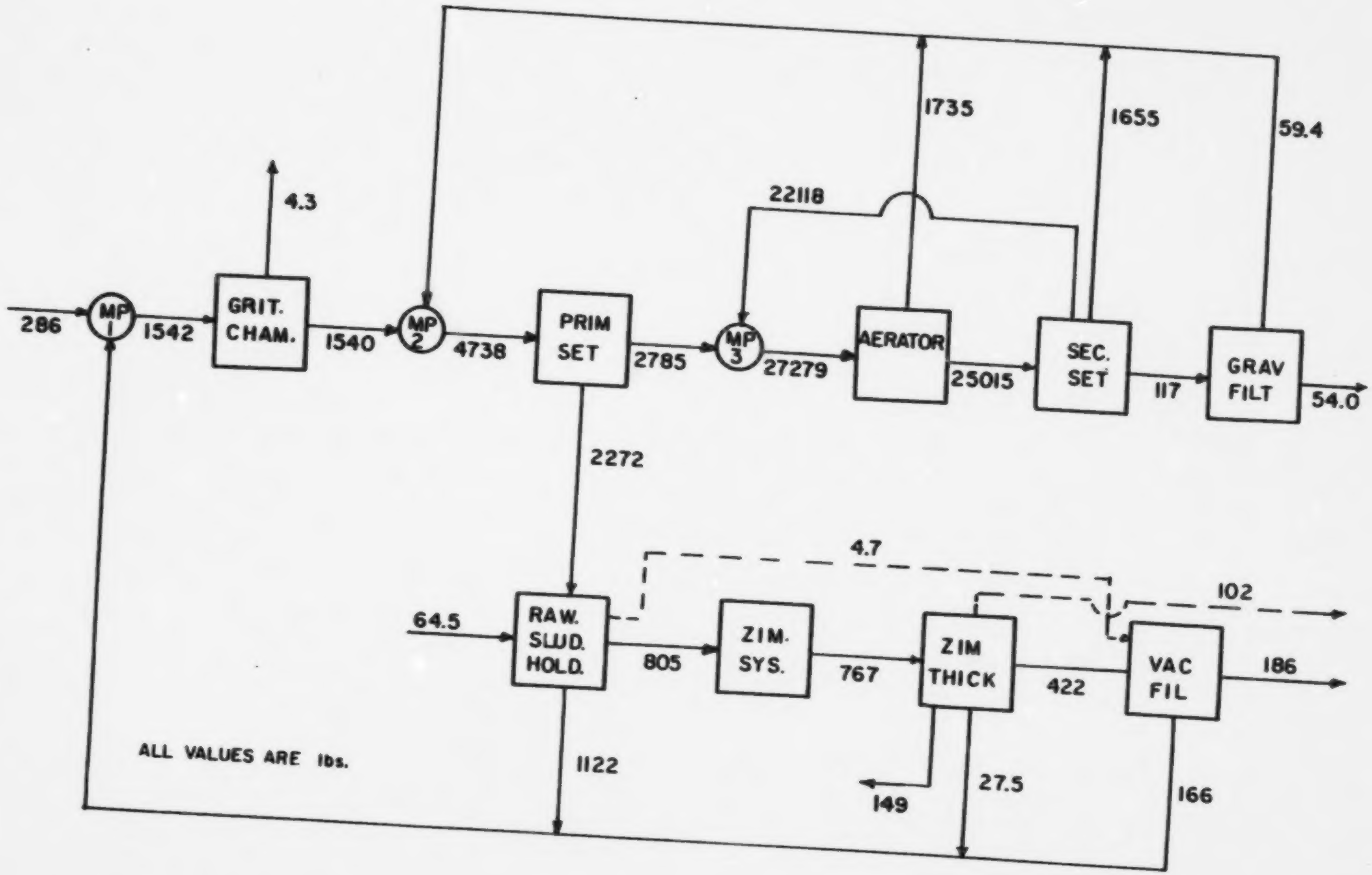

286
MP 1
1542
GRIT. CHAM.
4.3
1540
MP 2
4738
PRIM SET
2785
MP 3
27279
AERATOR
25015
SEC. SET
117
GRAV FILT
54.0
22118
1735
1655
59.4
2272
64.5
RAW. SLUD. HOLD.
805
ZIM. SYS.
767
ZIM THICK
422
VAC FIL
186
4.7
102
149
27.5
166
1122
ALL VALUES ARE lbs.

Figure 18. Cadmium mass balance.

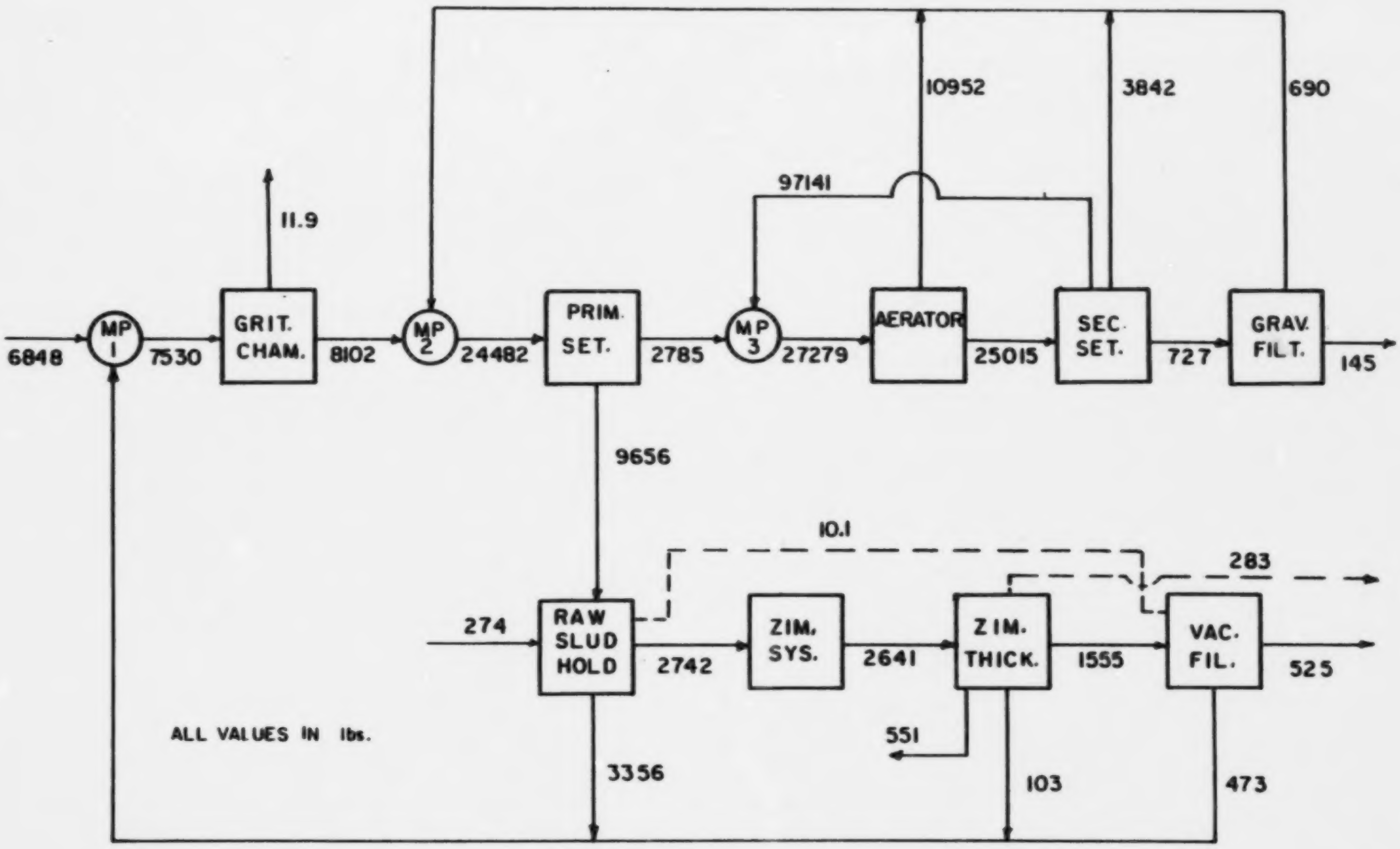

6848
MP 1
7530
GRIT. CHAM.
11.9
8102
MP 2
24482
PRIM. SET.
2785
MP 3
27279
AERATOR
25015
SEC. SET.
727
GRAV. FILT.
145
10952
3842
690
97141
9656
10.1
283
274
RAW SLUD HOLD
2742
ZIM. SYS.
2641
ZIM. THICK.
1555
VAC. FIL.
525
551
3356
103
473
ALL VALUES IN lbs.

Figure 19. Chromium mass balance.

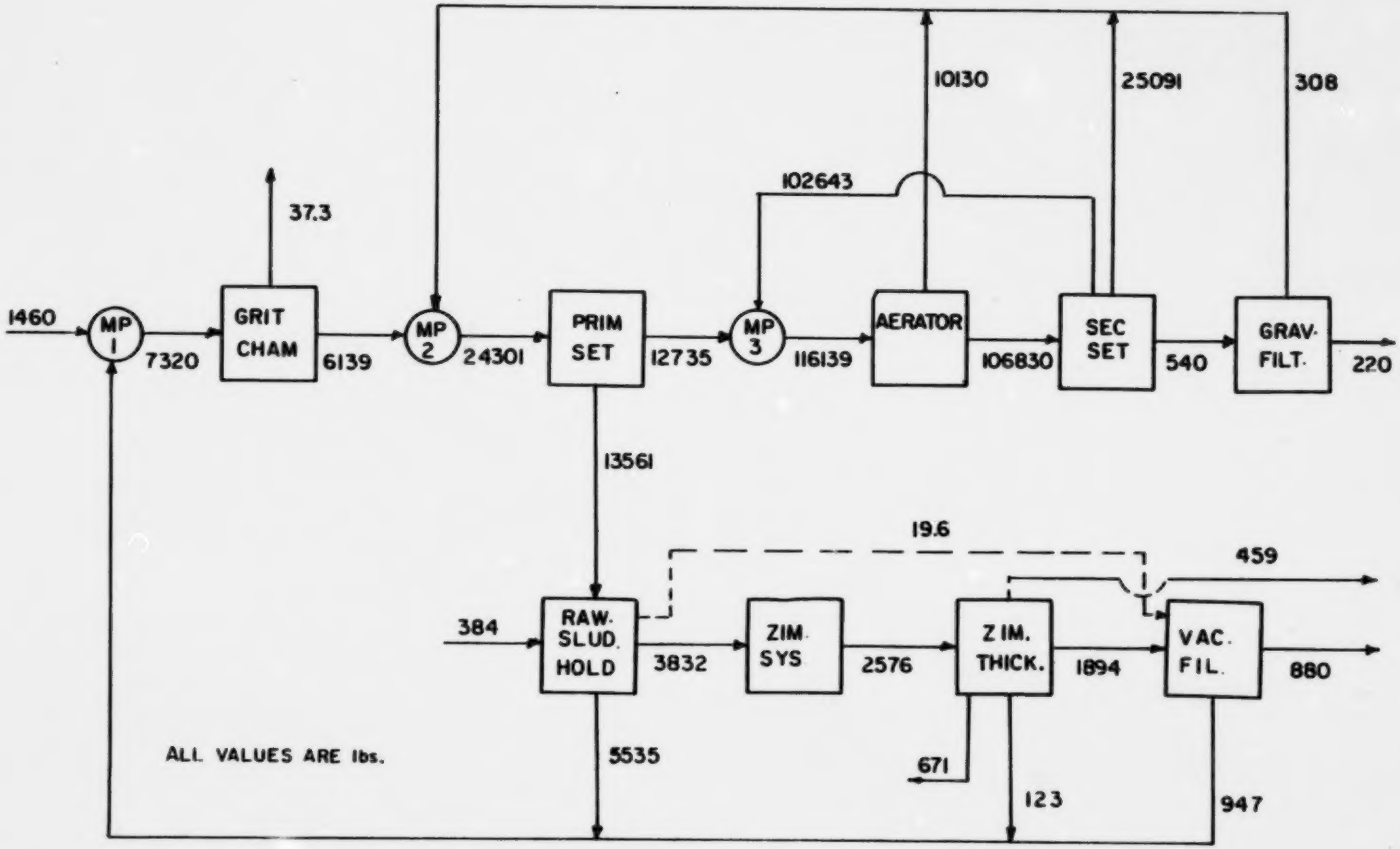

1460
MP 1
7320
GRIT CHAM
37.3
6139
MP 2
24301
PRIM SET
12735
MP 3
116139
AERATOR
106830
SEC SET
540
GRAV. FILT.
220
102643
10130
25091
308
13561
384
RAW. SLUD. HOLD
3832
ZIM. SYS
2576
ZIM. THICK.
1894
VAC. FIL.
880
19.6
459
5535
671
123
947
ALL VALUES ARE lbs.

Figure 20. Copper mass balance.

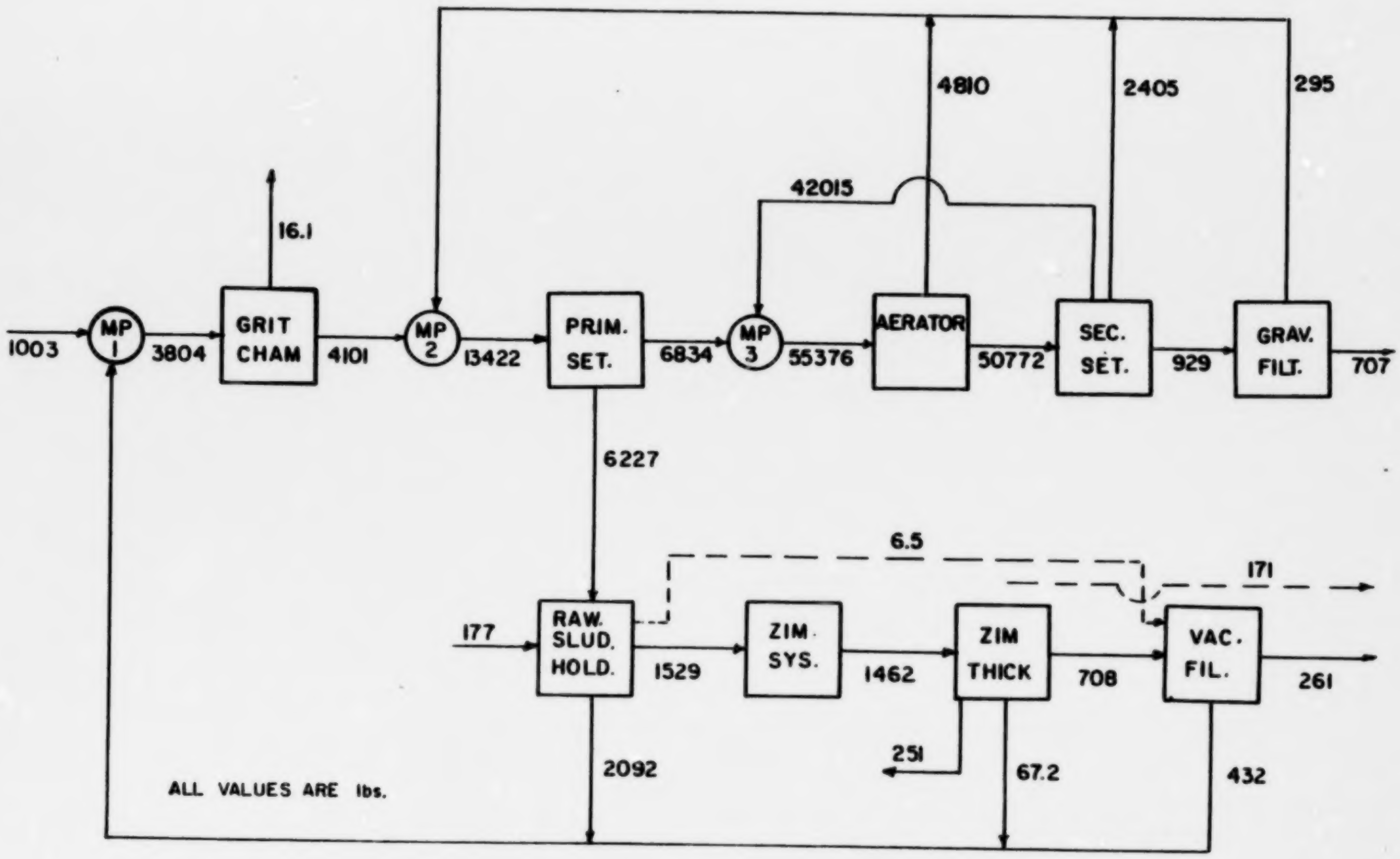

1003
MP 1
3804
GRIT CHAM
16.1
4101
MP 2
13422
PRIM. SET.
6834
MP 3
55376
AERATOR
50772
SEC. SET.
929
GRAV. FILT.
707
42015
4810
2405
295
6227
177
RAW. SLUD. HOLD.
1529
ZIM. SYS.
1462
ZIM THICK
708
VAC. FIL.
261
6.5
171
2092
251
67.2
432
ALL VALUES ARE lbs.

Figure 21. Nickel mass balance.

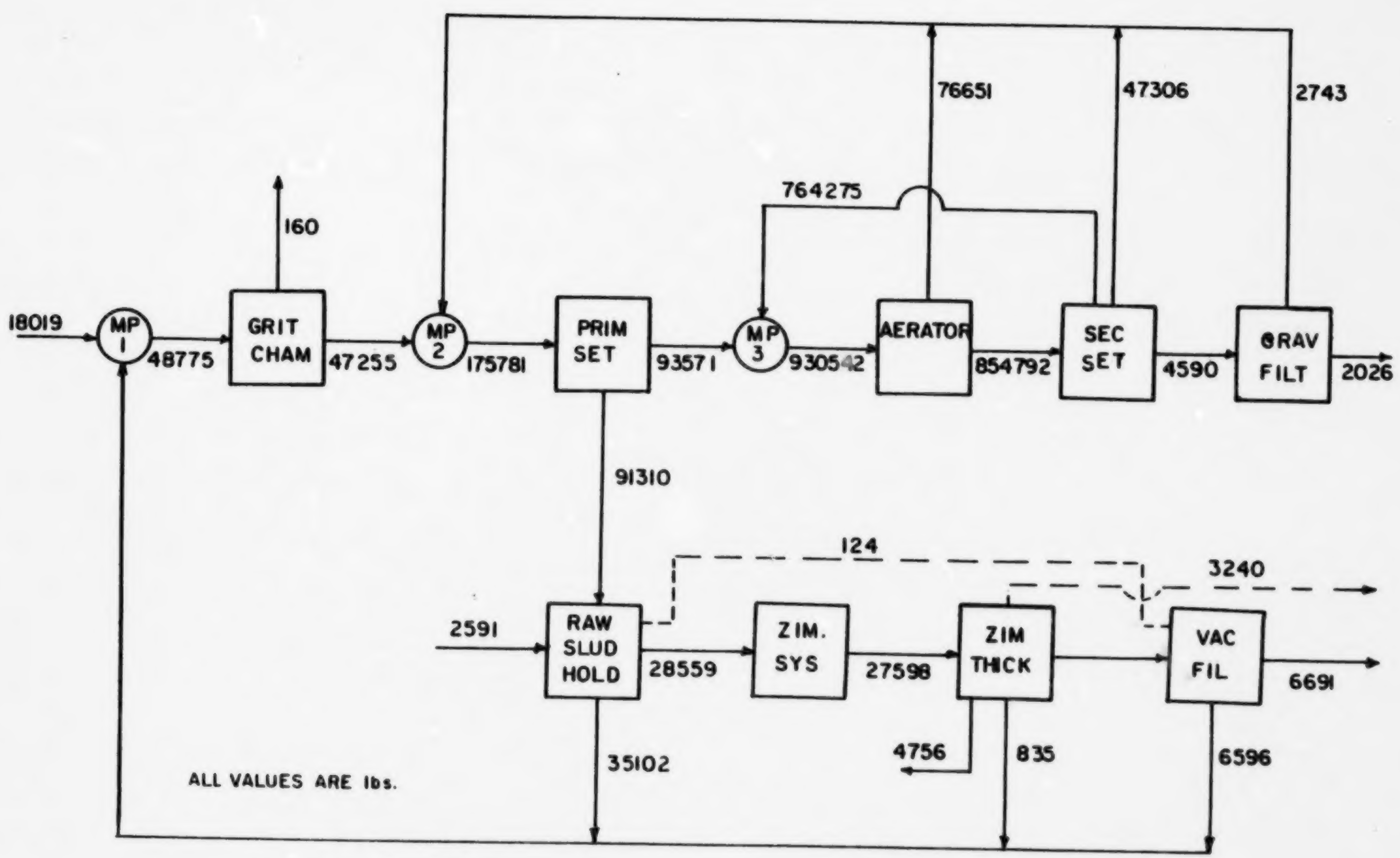
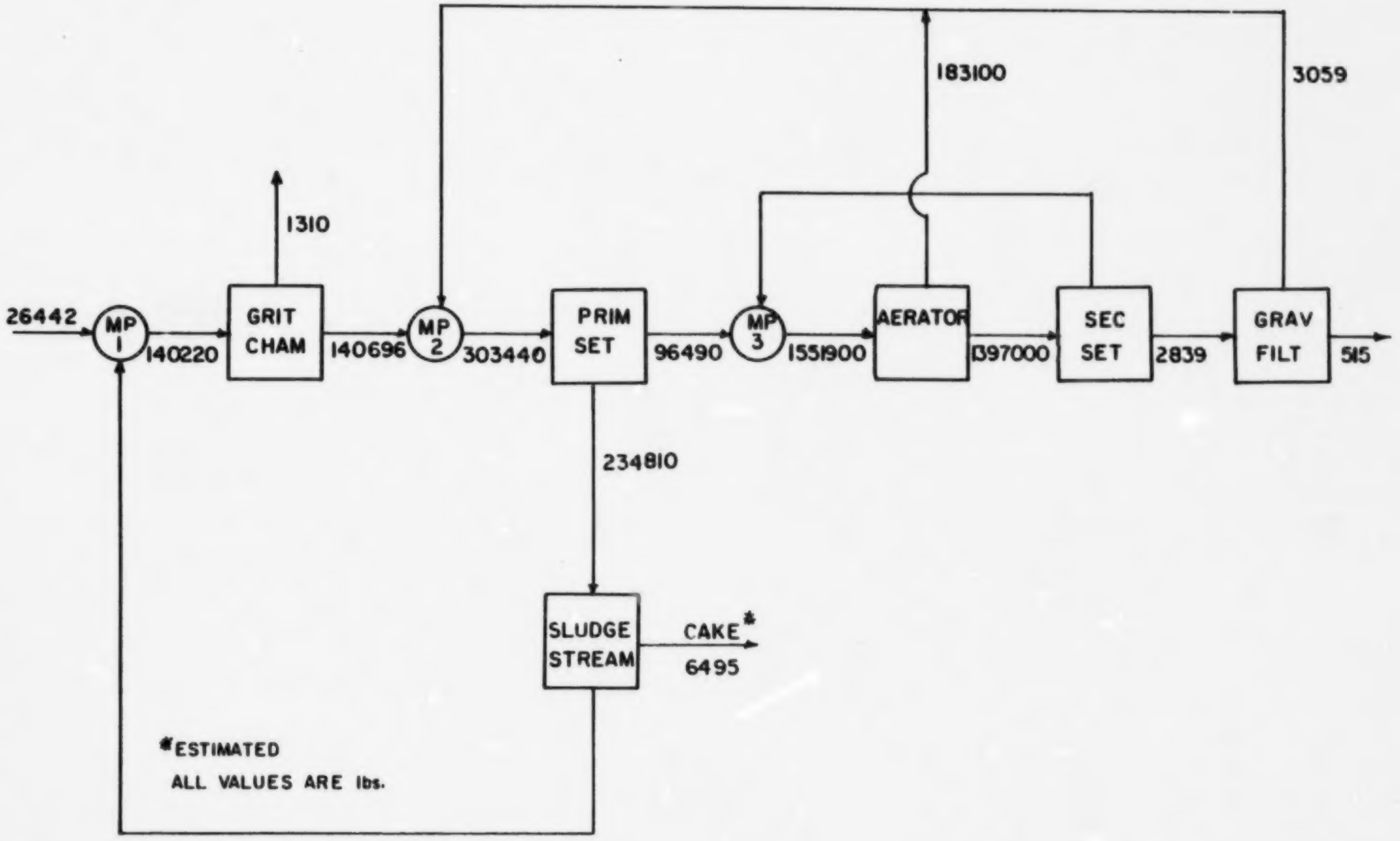

18019
MP 1
48775
GRIT CHAM
160
47255
MP 2
175781
PRIM SET
93571
MP 3
930542
AERATOR
854792
SEC SET
4590
GRAV FILT
2026
76651
47306
2743
764275
91310
2591
RAW SLUD HOLD
28559
ZIM. SYS
27598
ZIM THICK
VAC FIL
6691
124
3240
35102
4756
835
6596
ALL VALUES ARE lbs.

Figure 22. Zinc mass balance.


26442
MP 1
140220
GRIT CHAM
1310
140696
MP 2
303440
PRIM SET
96490
234810
MP 3
1551900
AERATOR
183100
1397000
SEC SET
2839
GRAV FILT
3059
515
SLUDGE STREAM
CAKE*
6495

*ESTIMATED
ALL VALUES ARE lbs.

Figure 23. Iron mass balance.

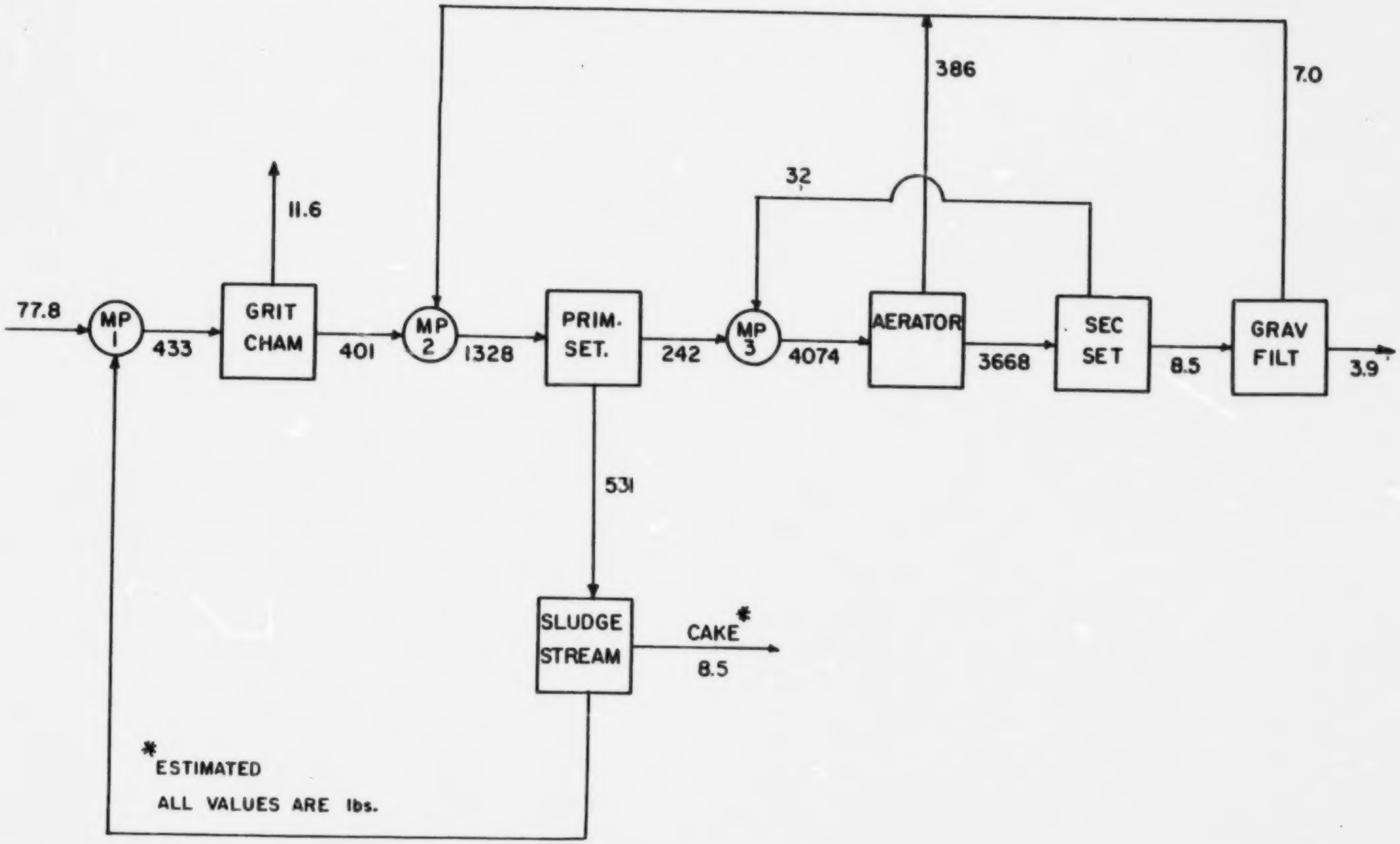

77.8
MP 1
433
GRIT CHAM
11.6
401
MP 2
1328
PRIM. SET.
242
MP 3
4074
AERATOR
3668
SEC SET
8.5
GRAV FILT
3.9
386
7.0
32
531
SLUDGE STREAM
CAKE*
8.5
*ESTIMATED
ALL VALUES ARE lbs.

Figure 24. Lead mass balance.

TABLE 53. SUMMARY OF MASS BALANCES

Unit Operation	Percent Recovery Cd	Cr	Cu	Ni	Zn	Fe	Pb
Mixing Point 1	99.5	69.8	90.8	105.8	80.6	-----	-----
Grit Chamber	100.1	107.8	84.4	108.2	97.2	101.2	95.2
Mixing Point 2	94.9	103.8	112.1	115.6	101.0	92.8	50.5
Primaries	106.7	100.0	108.2	97.3	105.2	109.2	58.2
Mixing Point 3	109.5	128.4	100.7	113.4	112.0	104.4	117.2
Aerators	98.1	99.5	100.7	100.4	100.1	101.8	99.5
Sec. Settlers	95.5	76.9	101.4	89.3	95.5	99.7	88.4
Grav. Filt.	97.7	114.9	97.8	107.9	103.9	125.9	128.2
Raw Sl. Hold T.	82.7	61.5	67.3	56.6	67.9	-----	-----
Zim. Reactors	95.3	96.3	67.2	95.4	96.6	-----	-----
Zim. Thickener	91.3	94.4	122.2	81.9	80.7	-----	-----
Vacuum Filters	92.5	63.8	95.5	97.1	98.0	-----	-----
Plant	142.0	21.3	123.0	119.1	81.9	----*	----*

* Note: Insufficient sampling period for balance.

TABLE 54. FRACTION OF INFLUENT METAL IN THE SLUDGE

	Fraction of Influent[1] Mass of Metal Cd	Cr	Cu	Ni	Zn
Primary Sludge	0.48	0.39	0.56	0.46	0.52
Filter Cake	1.01	0.12	0.91	0.43	0.55

[1] Based on primary influent and plant influent for primary sludge and filter cake respectively. Mass in filter cake sludge includes mass in lagoon feed also.

The percent of recovery of chromium about the plant is also very low because, first, the cake concentration is too low. The average concentration reported as 1,060 mg/kg. The Kokomo lab has reported chromium levels of 3,000 to 4,000 mg/kg over the past year. The low percent of recovery of chromium about the vacuum filters (63.8 percent), with no correspondingly low value about the Zimpro thickener, as in zinc, also points to the error in chromium concentration in the filter cake. This error probably arises for the same reason as did the zinc error, i.e., the excessively high dilutions needed for chromium in the filter cake, 1,000:1. However, the measured chromium concentration in the sludge ranged from 207 to 541 mg/kg on a wet-weight basis, with an average of 426 and standard deviation of only 66 mg/l, which would indicate consistent analytical results. Second, the high concentration of chromium in the plant influent is a problem. The mass balance about mixing point 1 bears this out (69.8 percent recovery). This high value was largely due to a spike of 5.33 mg/l chromium received by the plant on Day 55. This was one of the days that a profile of the influent metal as a function of time was done. If a large spike entered the plant for a short period at the time that a sample was collected, that concentration was assumed to be entering the plant for a four-hour period. While this may be true of a typical sample, it is not true, by definition, of a spike, so an actual average influent concentration may be lower. Other extremely high values were reported on Days 21 and 34.

Another discrepancy is the uniformly low percent of recoveries reported for the raw-sludge holding tank which could be due to sampling problems or errors in flow-rate measurement. Table 27 indicates that the hydraulic balance only accounted for 80.3 percent of the influent flow which could account for the percent of recoveries about the tank, shown in Table 46. There possibly also were errors in sampling procedure since, if the supernatant were not sampled at the operation's midpoint, as specified, but rather near the start, an excessively dilute sample resulted.

The only other major data error for the five metals is the low percent of recovery for chromium about the secondary clarifiers and the high percent of recovery about mixing point 3. This arises from the same source--a low measured chromium concentration in the RAS. Since the other metals at these points to not have this, it indicates an experimental error in chromium determination.

The mass balances for iron and lead appear reasonable considering the limited sampling period and relative insensitivity of AA toward iron and lead.

Patterns and Effects of Heavy Metals

Raw data generated during this project can be manipulated many different ways, and used with lab data from the treatment plant, it can possibly identify effects of heavy metals on the treatment process.

The daily mass of metal entering the plant is shown in Figures 25 to 30. The periodic pattern of the day-to-day metal influent is the most striking observation. Cadmium is the most pronounced in this regard. Sundays are

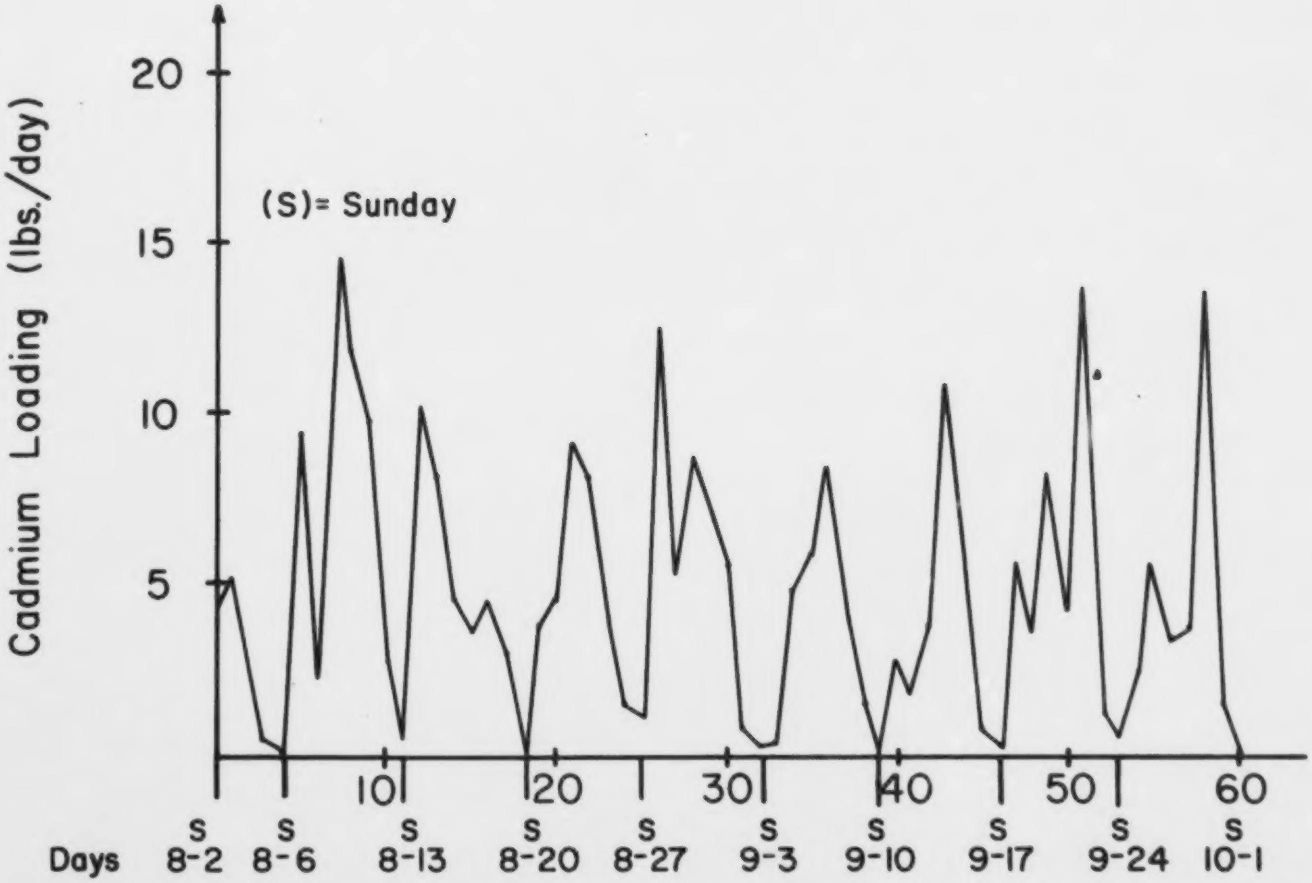


Figure 25. Influent cadmium loading to plant during study.

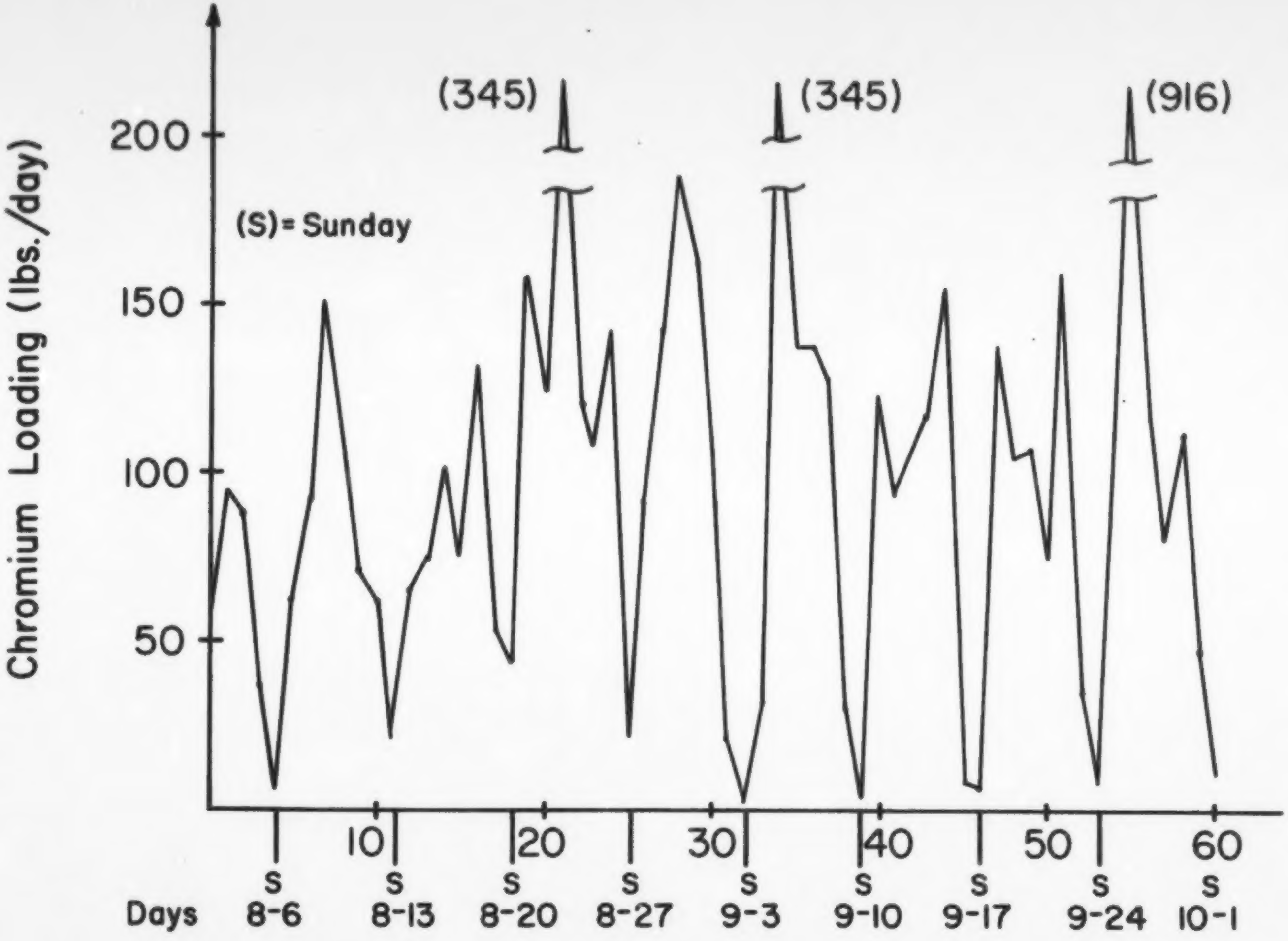


Figure 26. Influent chromium loading to plant during study.

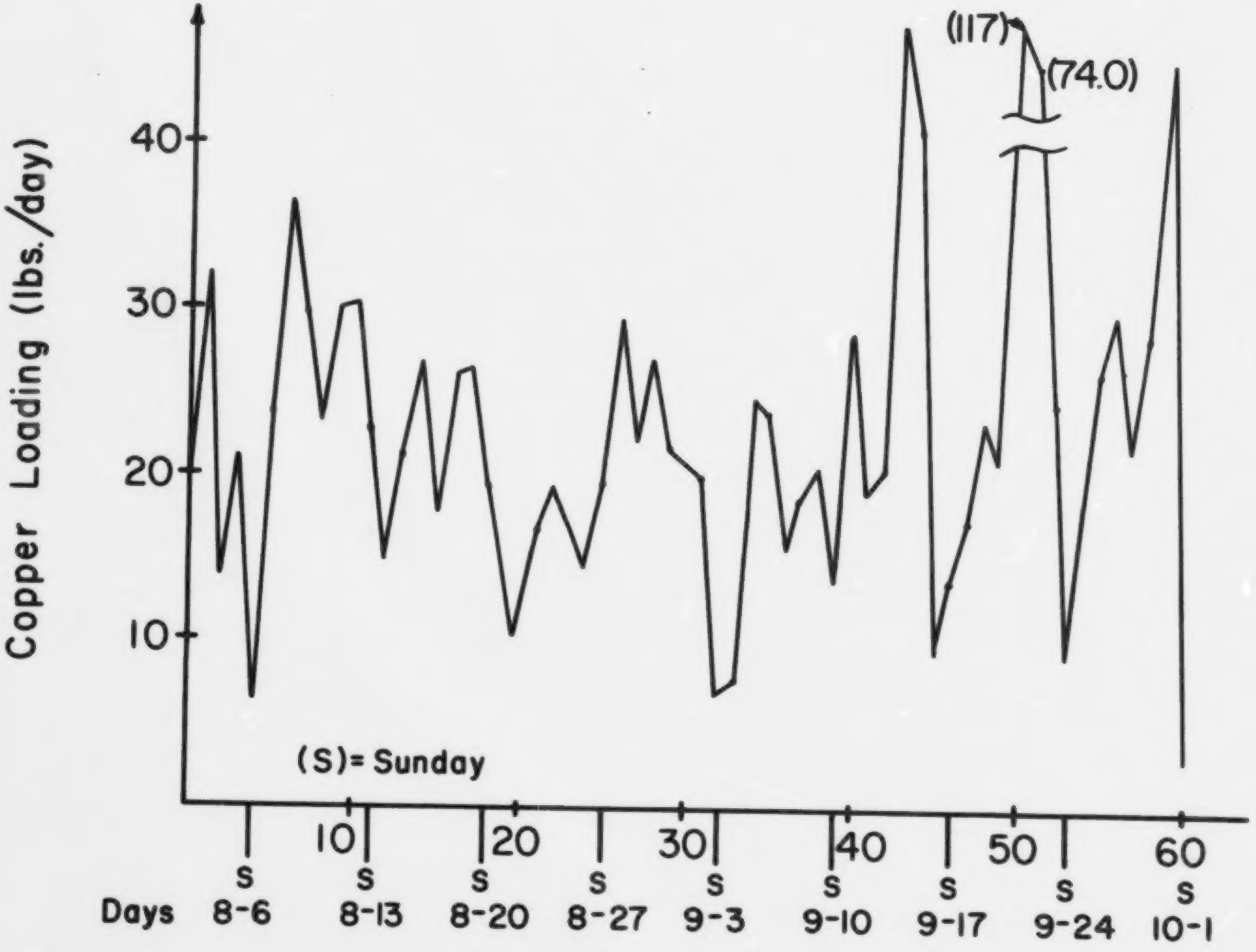


Figure 27. Influent copper loading to plant during study.

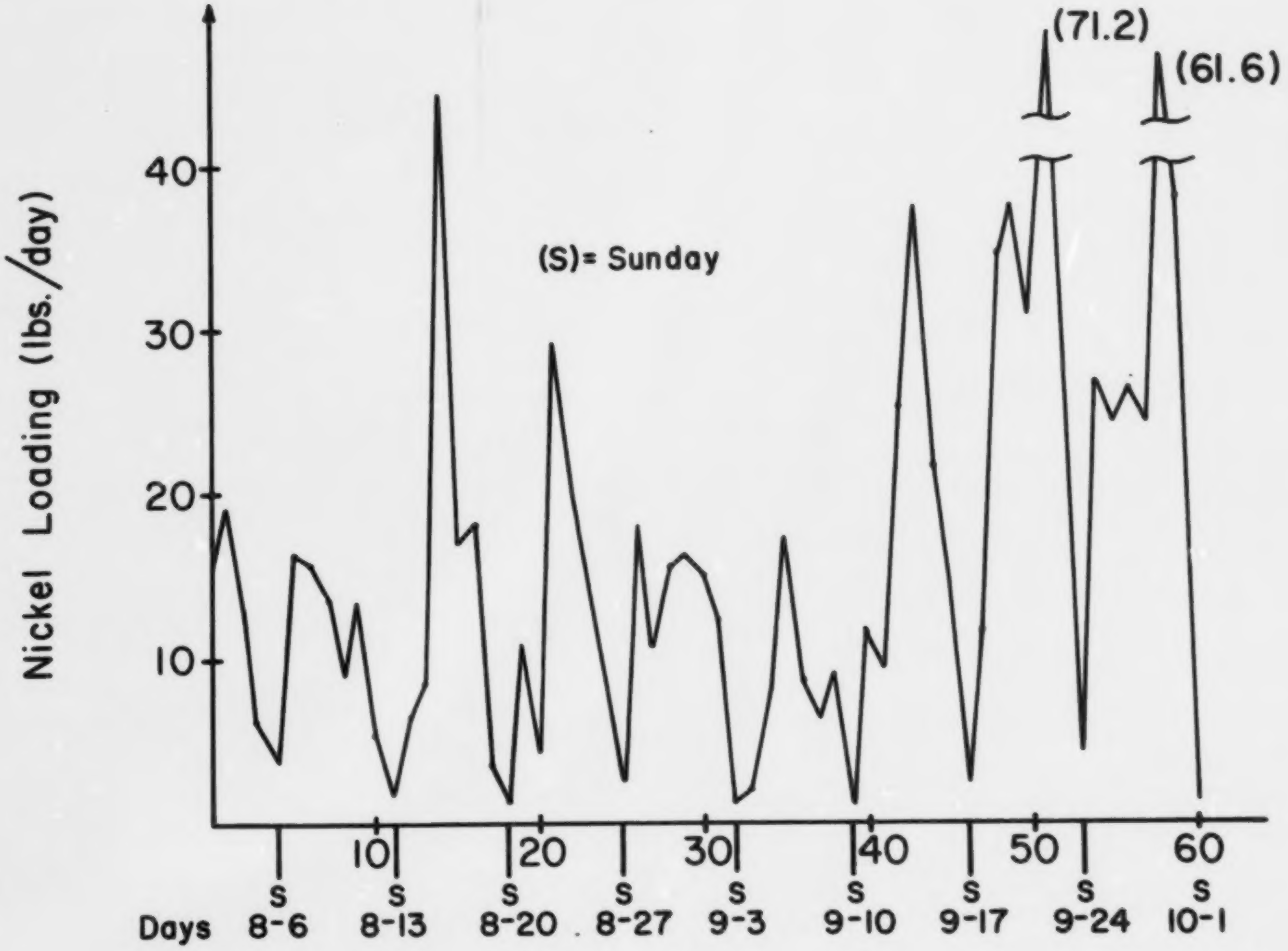


Figure 28. Influent nickel loading to plant during study.

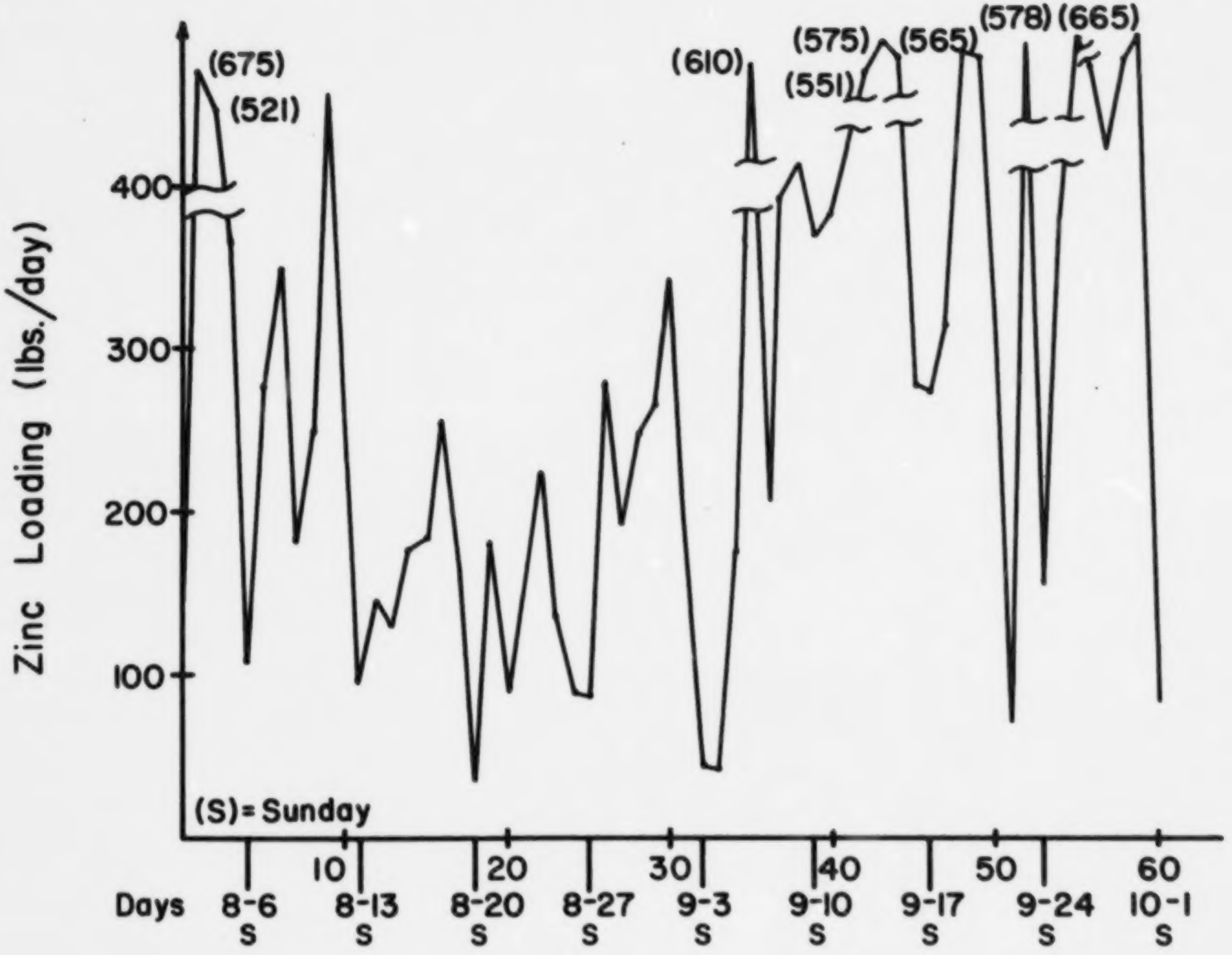


Figure 29. Influent zinc loading to plant during study.

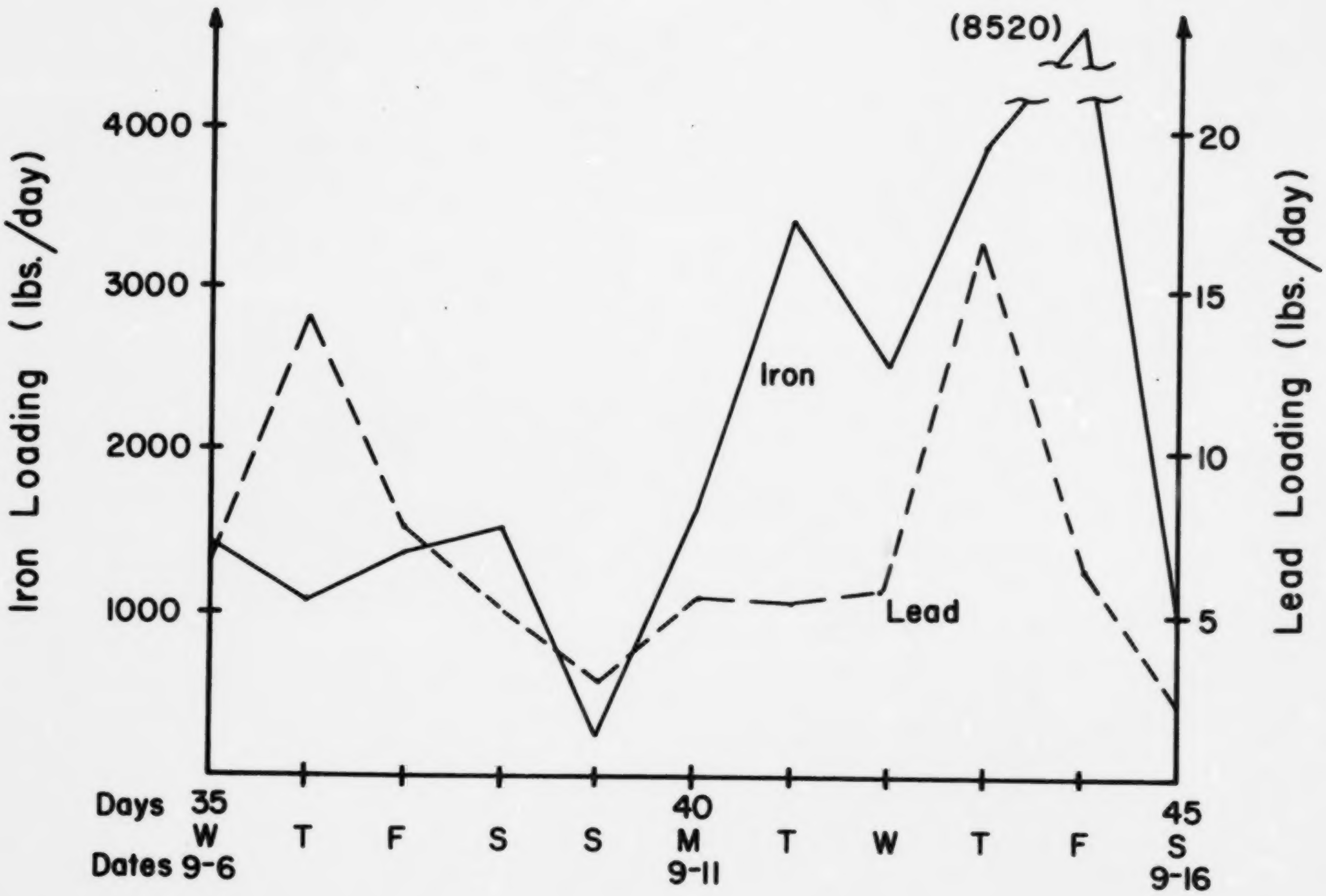


Figure 30. Influent iron and lead loading to plant during study.

identified with "S" on each graph, and show the mass of influent metal drops significantly on weekends, which would indicate an industrial source for metals. Also, on Day 33, a Labor Day Monday holiday, the heavy metal level entering the plant was essentially the same as a Sunday. Generally, Saturdays were also low, but not as low as Sundays because there probably was some industry activity. Cadmium has the most regular pattern, and chromium the most variable. The daily influent metal can vary from over 900 lbs to under 10 lbs in a week. Copper has the least regular pattern which might point to significant copper sources other than industry, such as domestic or runoff/infiltration. Although data were collected for only 11 days, iron and lead had low Sunday inputs.

The low Sunday inputs are not due to the lower flow rate over the weekends because the average flow Monday through Friday was 18.6 mgd, while Saturday and Sunday was 14.5 mgd, hardly the 40- to 50-fold difference in metal loadings for these periods. Unlike low period regularity, peak loadings showed irregularity, for example, peaks in cadmium concentration occurred on Wednesday, Monday, Wednesday, Monday, Thursday, Thursday, Friday, and Friday during successive weeks.

A limited study examined the diurnal variation of the metals on Days 55, 56, and 57 for each influent sample without compositing. Figures 31 and 32 contain results and again reveal some very interesting patterns. Each metal has a pattern of regularity, but the peaks and valleys occur at different times. Cadmium and zinc peak in the morning, nickel and copper in the early afternoon, and chromium in the early morning. With a sewer system as large as Kokomo's, it is difficult to determine exact discharge time because the different sources are located at varying distances from the treatment plant. The data show discharge characteristics of industrial sources rather than domestic. The maximum hourly flow recorded during this three-day period was 28.3 mgd; the lowest, 12.4 mgd.

The Kokomo plant uses a Zimpro system and vacuum filters to process sludge, so the data were analyzed for significant effects from these systems on metal loading in the treatment plant. Table 55 shows this analysis under several designations:

(1) the average condition,
(2) with either the vacuum filter or Zimpro on-line,
(3) when neither is on-line,
(4) when both are on-line,
(5,6) when each is on-line regardless of the other, and
(7,8) when only each one is on-line.

The grit chamber influent was the influent metal concentration, as this was the first sampling point downstream from where the Zimpro supernatant and vacuum filter filtrate combine with plant influent. As columns 1 to 3 show, the sludge handling systems have no consistent effect on metal loading. In fact, the data indicate that no combination of systems has an effect. The primary effect of sludge handling systems increases the effluent biochemical oxygen demand (BOD) and primary effluent suspended solids. The frequency of

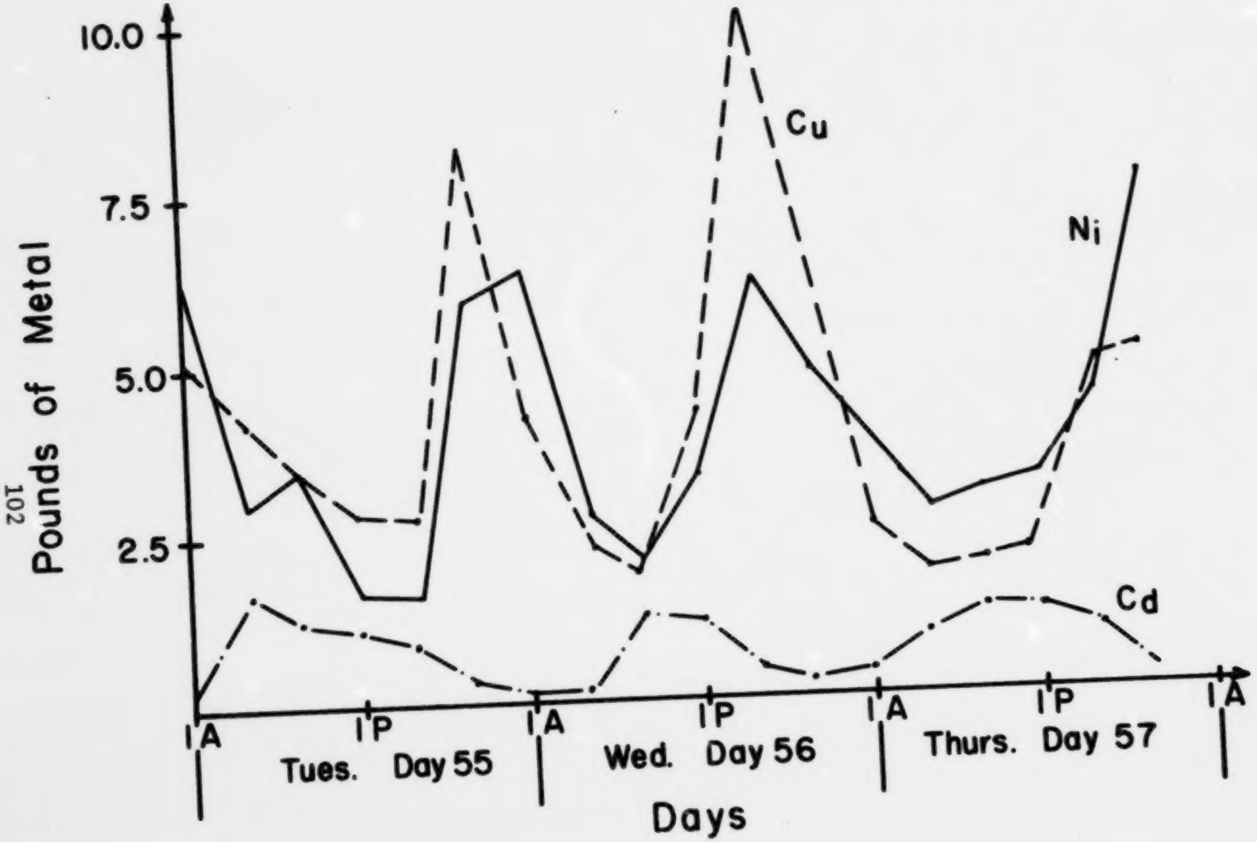


Figure 31. Diurnal variation of influent Cd, Cu, and Ni.

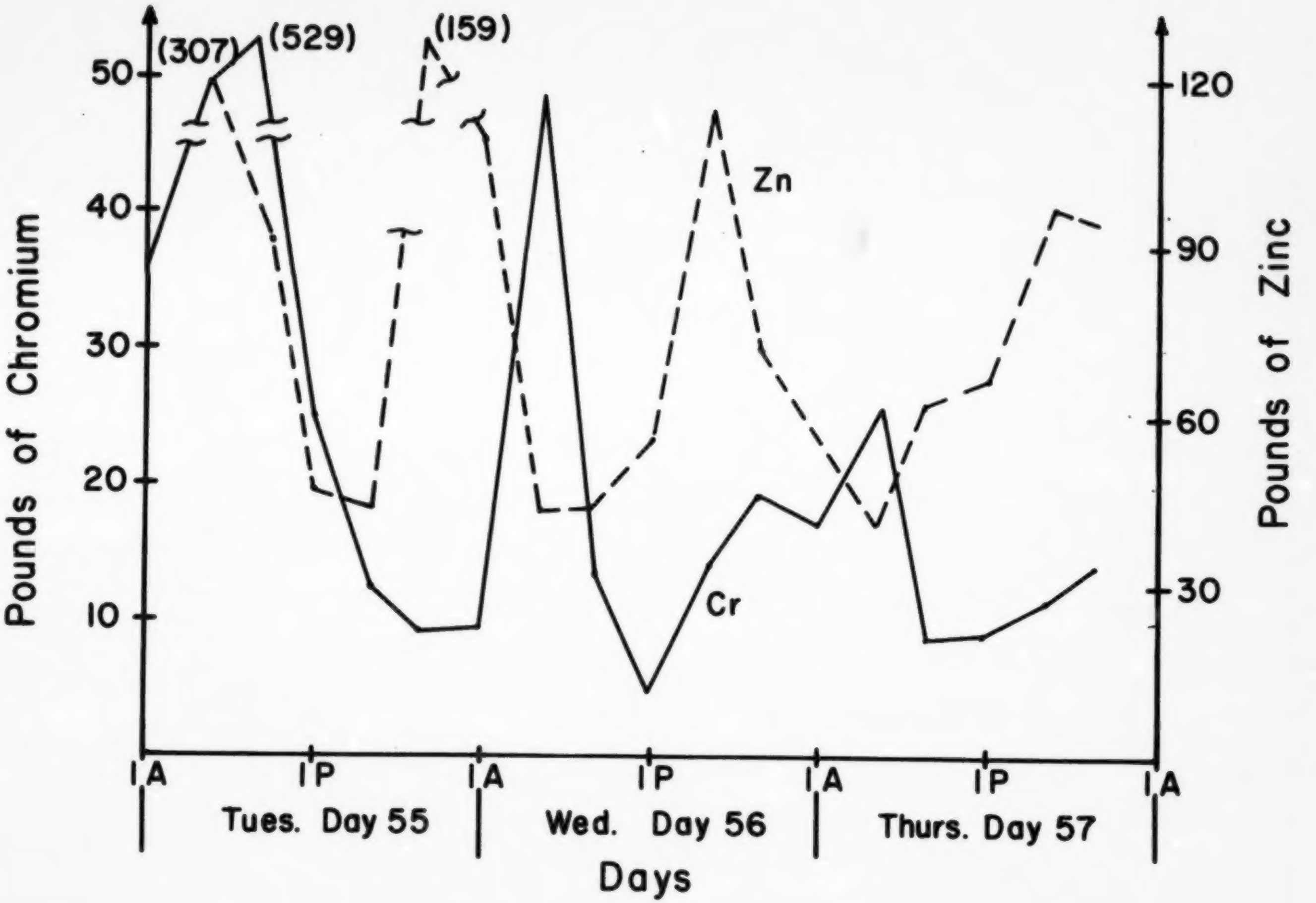


Figure 32, Diurnal variation of influent Cr and Zn.

TABLE 55. EFFECTS OF ZIMPRO SYSTEM AND VACUUM FILTERS ON METAL LOADING AND TREATMENT EFFICIENCY

Quantity	(1) Avg.	(2) V.F. and/or Zimpro	(3) Neither	(4) V.F. and Zimpro	(5) Vac. Filter	(6) Zimpro	(7) V.F. Only	(8) Zim. Only
Flow mgd	17.4	18.0	16.0	19.0	17.3	17.9	16.2	16.2
Days Oper.	60	41	19	33.5	33.5	32.5	6.5	6.5
Cd Loading (mg/l)	0.177	0.147	0.249	0.158	0.156	0.154	0.165	0.0914
Cd in Eff.	0.00631	0.00673	0.00533	0.00554	0.00479	0.00538	0.00693	0.0107
Cr Loading (mg/l)	0.864	0.848	1.01	0.876	0.844	0.886	0.959	0.538
Cr in Eff.	0.0167	0.0160	0.0185	0.00823	0.00646	0.0133	0.0145	0.0525
Cu Loading (mg/l)	0.841	0.279	1.33	0.590	0.669	0.627	1.07	0.417
Cu in Eff.	0.0252	0.0264	0.0225	0.0193	0.0180	0.0209	0.0299	0.0461
Ni Loading (mg/l)	0.437	0.437	0.437	0.295	0.464	0.334	1.06	0.276
Ni in Eff.	0.0812	0.0849	0.0728	0.0573	0.0616	0.0655	0.105	0.128
Zn Loading (mg/l)	5.60	5.33	6.25	5.58	3.72	5.52	7.73	4.31
Zn in Eff.	0.233	0.232	0.237	0.151	0.130	0.183	0.264	0.564
Plant Eff. BOD (mg/l)	30.8	33.8	24.4					
Plant Eff. SS (mg/l)	7.7	7.7	7.7					
Sec. Eff. BOD (mg/l)	32.0	34.9	25.1					
Sec. Eff. SS (mg/l)	26.1	28.5	20.3					
Raw Sludge Flow (mgd)	0.189	0.190	0.187					
Filter B.W. Flow (mgd)	1.10	1.26	0.67					
Pr. Eff. SS (mg/l)	617	647	546					

backwashing also increases when the Zimpro system and vacuum filter go on-line, however, since these effects are not directly related to heavy metals, no additional study was done.

The weekly pattern of effluent BOD_5 was examined, anticipating a correlation to metal loading. As Figure 33 shows, no long-term pattern related to the weekly variation of heavy metal loading with peaks during the week and low points on weekends. A weekly pattern seems to exist from about days 20 to 50 when the effluent BOD_5 decreases on weekends. However, heavy metals are not solely responsible since this decrease is absent from the rest of the sampling period. These results are consistent with other findings that the treatment process recovers very rapidly from a metal spike. Also, Kokomo's plant has been acclimated to high metal loading for a long time, so results are not surprising.

Figures 34 to 39 show the frequency distribution of each of the seven heavy metal concentrations in the plant effluent. These distributions are plotted, using a logarithmic ordinate scale, necessitated by the wide range in measured effluent concentrations. Distribution curves indicate that they may really result from two log-normal distributions superimposed on one another. At higher concentrations, one log-normal distribution may account for plant upsets. At lower concentrations another distribution may account for day-to-day variability in plant effluent. These two distributions characterize plant removal of heavy metals.

Finally, several attempts were made to correlate metal concentrations to suspended solids. It was hoped a linear relationship would result, for example:

$$\text{Metal Conc.} = (\text{Const}_1)\ (\text{SS}) + (\text{Const}_2).$$

If so, soluble metal could be estimated as (Const_2). However, when done at several treatment plant points, for example, the plant influent, the primary influent and effluent, the MLSS, the secondary and plant effluent, no correlation was possible. Correlation coefficients for a linear least-squares fit ranged from -0.09 to 0.06.

CONCLUSIONS

(1) The Kokomo, Indiana, activated sludge, municipal sewage treatment plant is capable of high removals of heavy metals. Influent concentrations are reduced 80 percent for cadmium, 98 percent for chromium, 85 percent for copper, 29 percent for nickel, 89 percent for zinc, 98 percent for iron, and 95 percent for lead.

(2) High and variable influent metal concentrations do not significantly affect this acclimated treatment plant, either with regard to metal removal efficiencies or to five-day BOD_5 and suspended solids (SS) removal efficiencies.

(3) A mass balance for heavy metals in a treatment plant can be reasonably accomplished. Percent recoveries (percentage of mass of influent metal from effluent of a particular operation) are consistently between 90 and 110 percent for all mainstream operations. Recoveries around sludge-handling operations are consistently between 80 and 120 percent. Around the whole plant, recoveries were measured as follows: cadmium, 142 percent; copper, 123 percent; nickel, 119 percent; and zinc, 82 percent. Chromium recovery was only 21 percent, which was believed to be the result of a low measured chromium concentration in the filter cake and/or several very large influent chromium spikes. Recoveries for iron and lead were in the same range as the other metals in unit operations, however, there was an insufficient sampling period for a meaningful balance for the plant as a whole.

(4) Metals are conserved within the treatment plant and ultimately concentrate to a very high degree in the final sludge cake. The average metal concentrations of the filter cake were on a dry weight basis 377 mg/kg for cadmium, 1,060 mg/kg for chromim, 1,970 mg/kg for copper, 533 mg/kg for nickel, 13,600 mg/kg for zinc, 71,900 mg/kg for iron, and 94 mg/kg for lead.

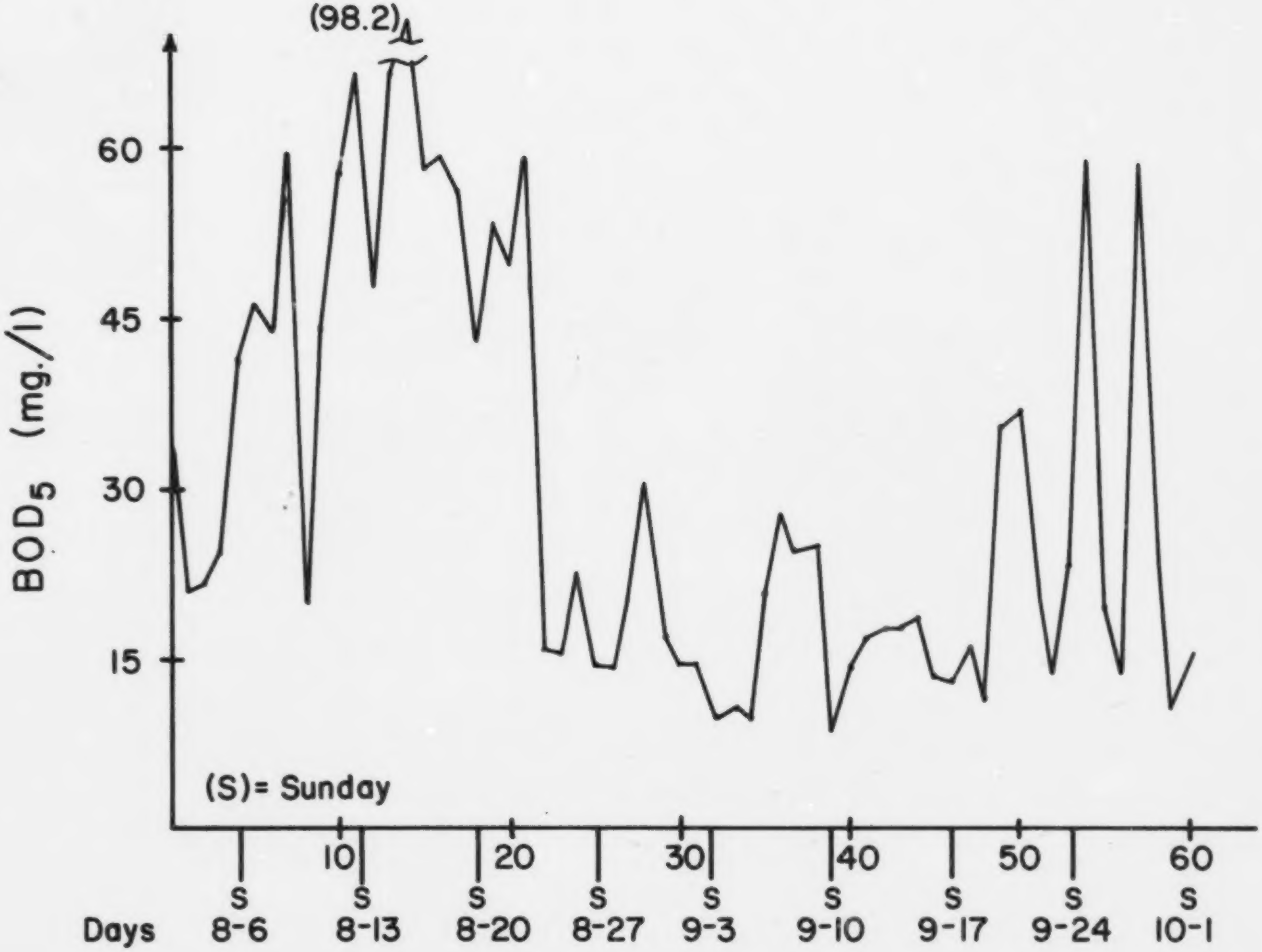


Figure 33. Secondary effluent BOD_5.

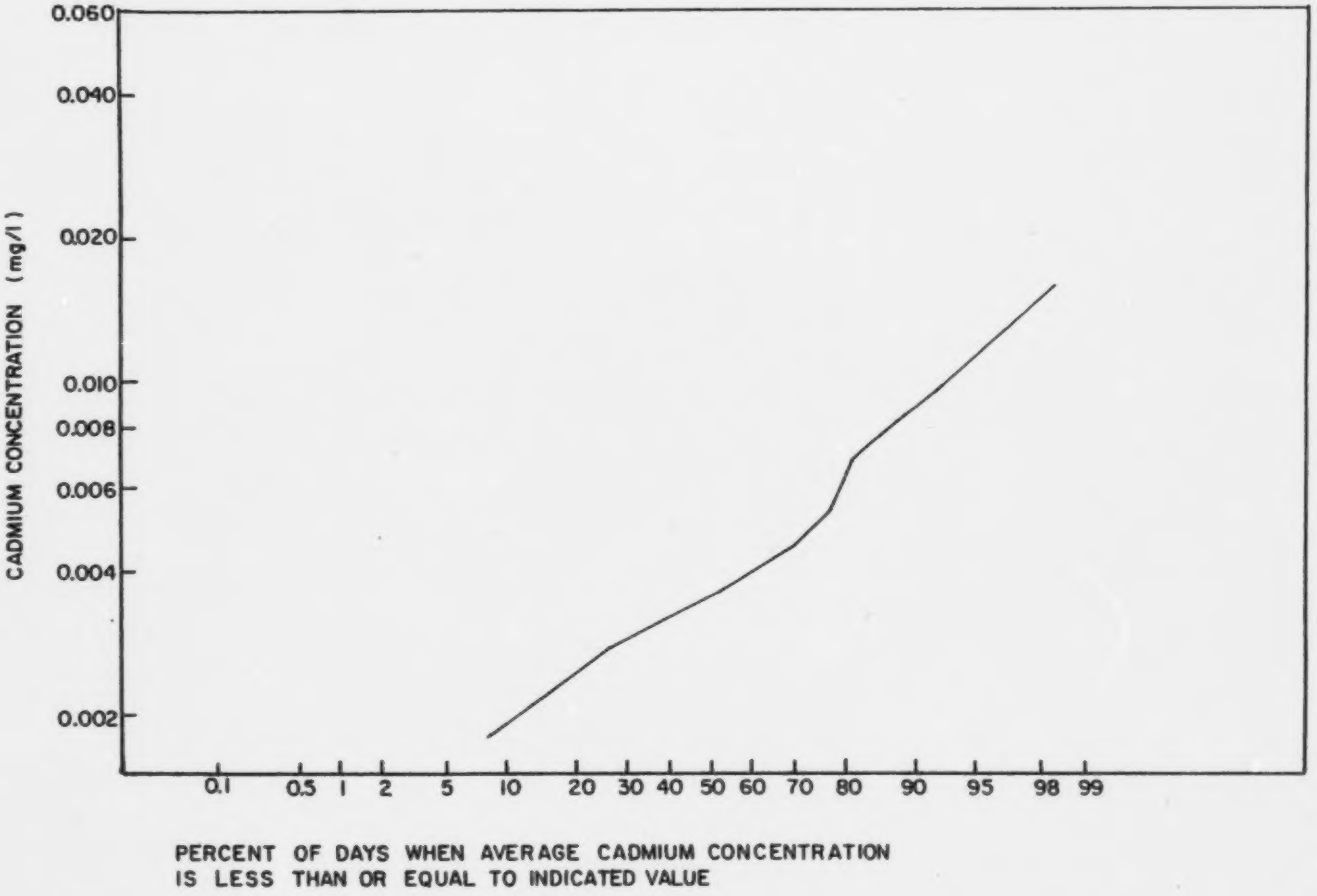


Figure 34. Effluent cadmium frequency distribution.

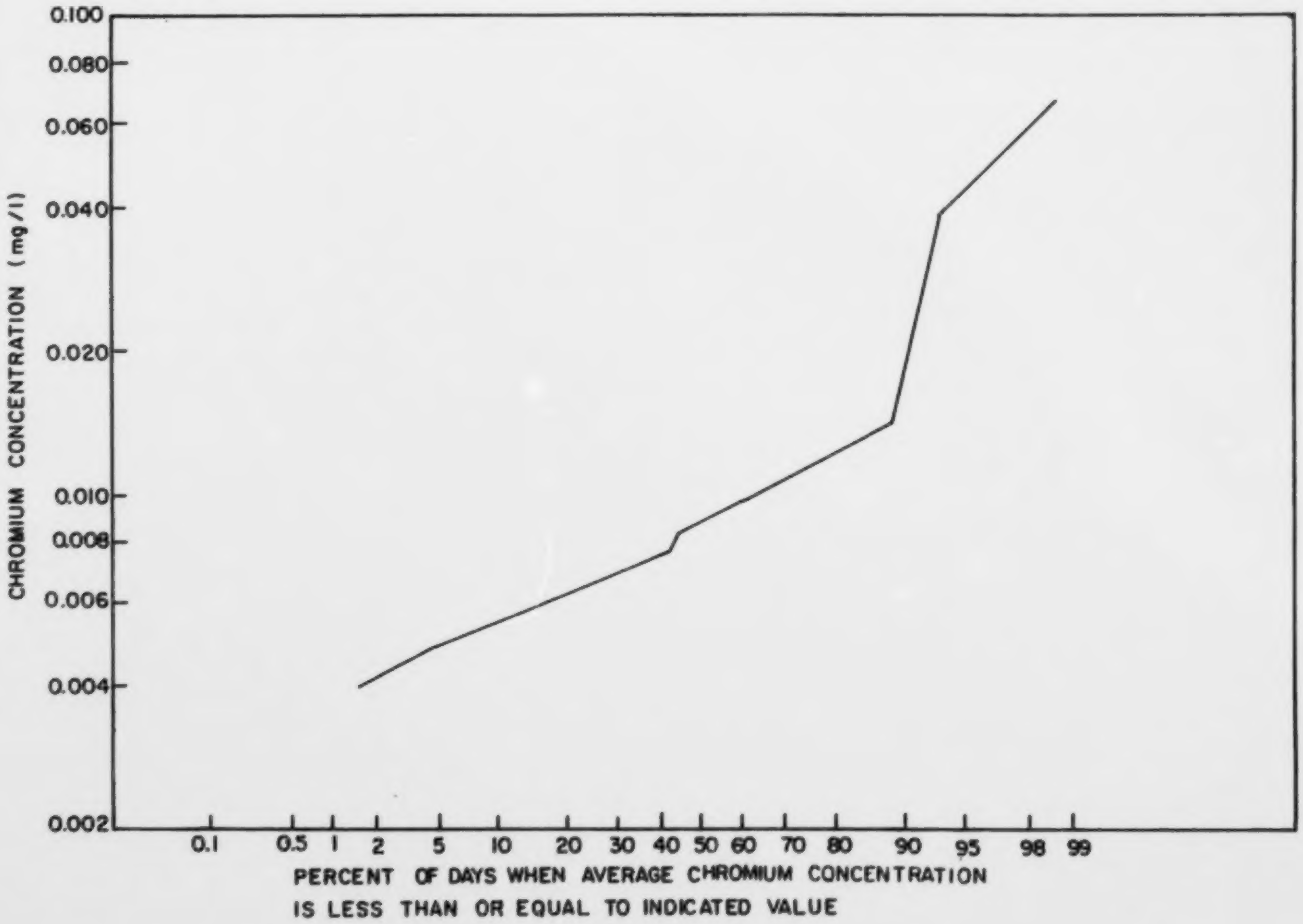


Figure 35. Effluent chromium frequency distribution.

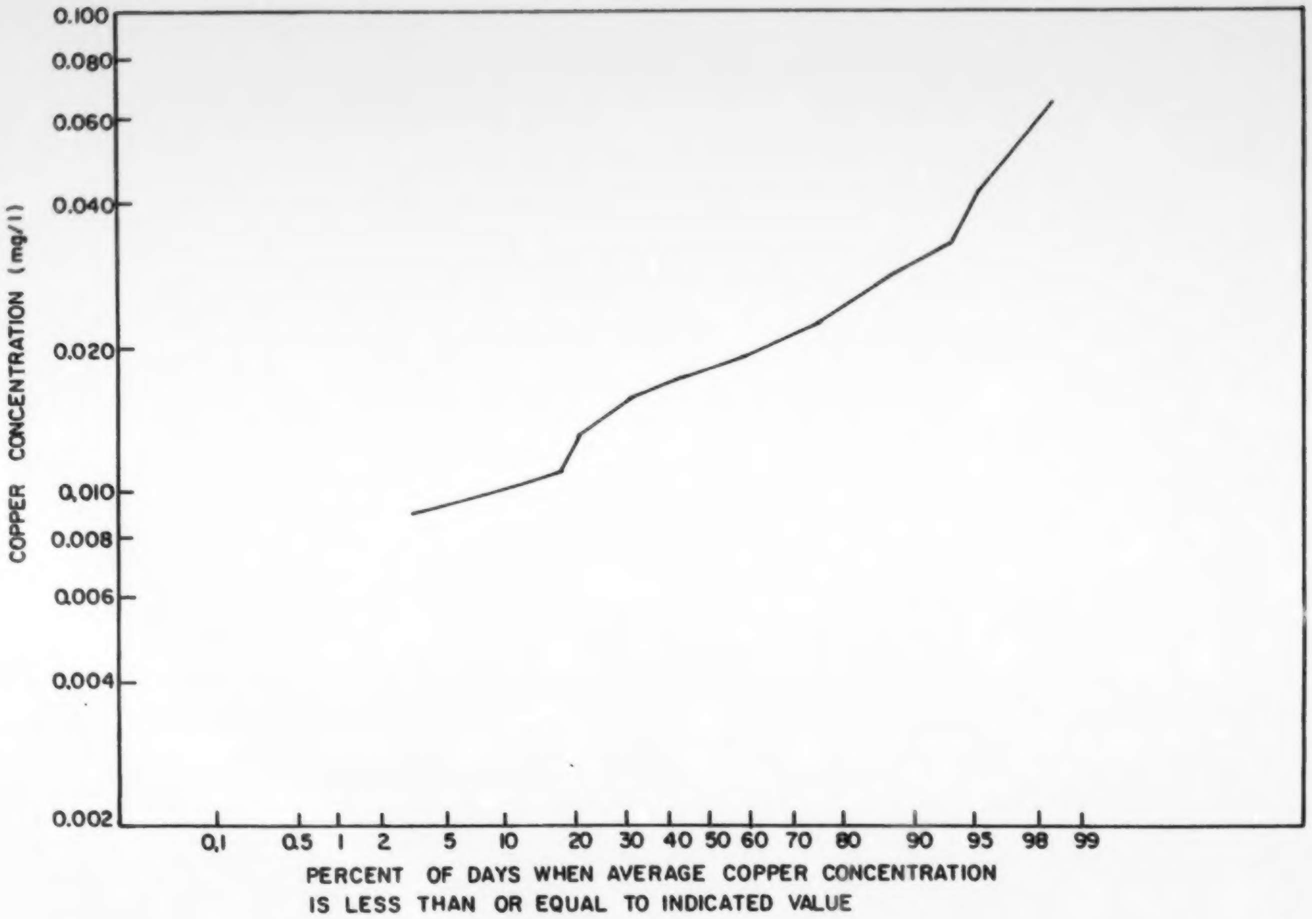


Figure 36. Effluent copper frequency distribution.

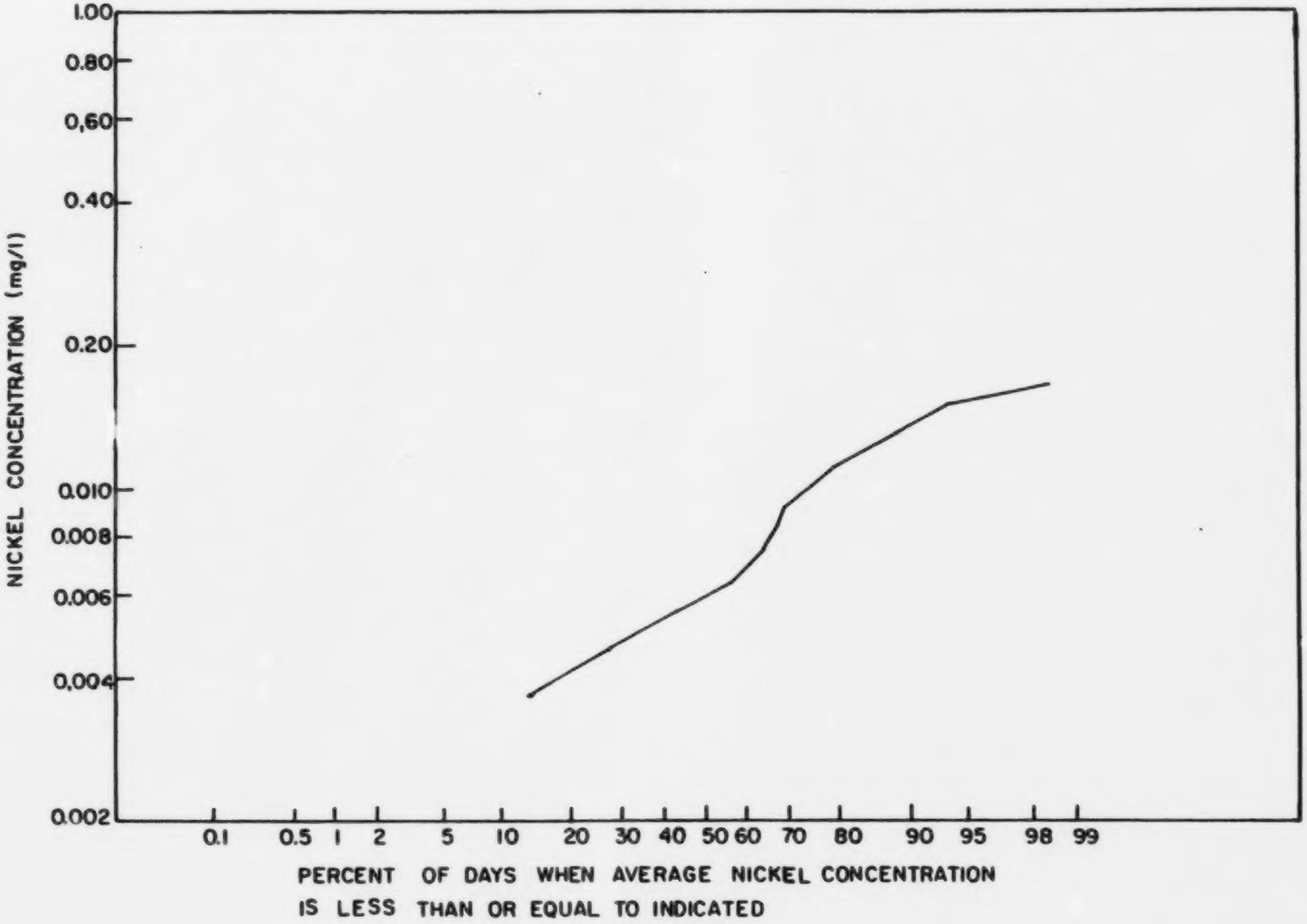


Figure 37. Effluent nickel frequency distribution.

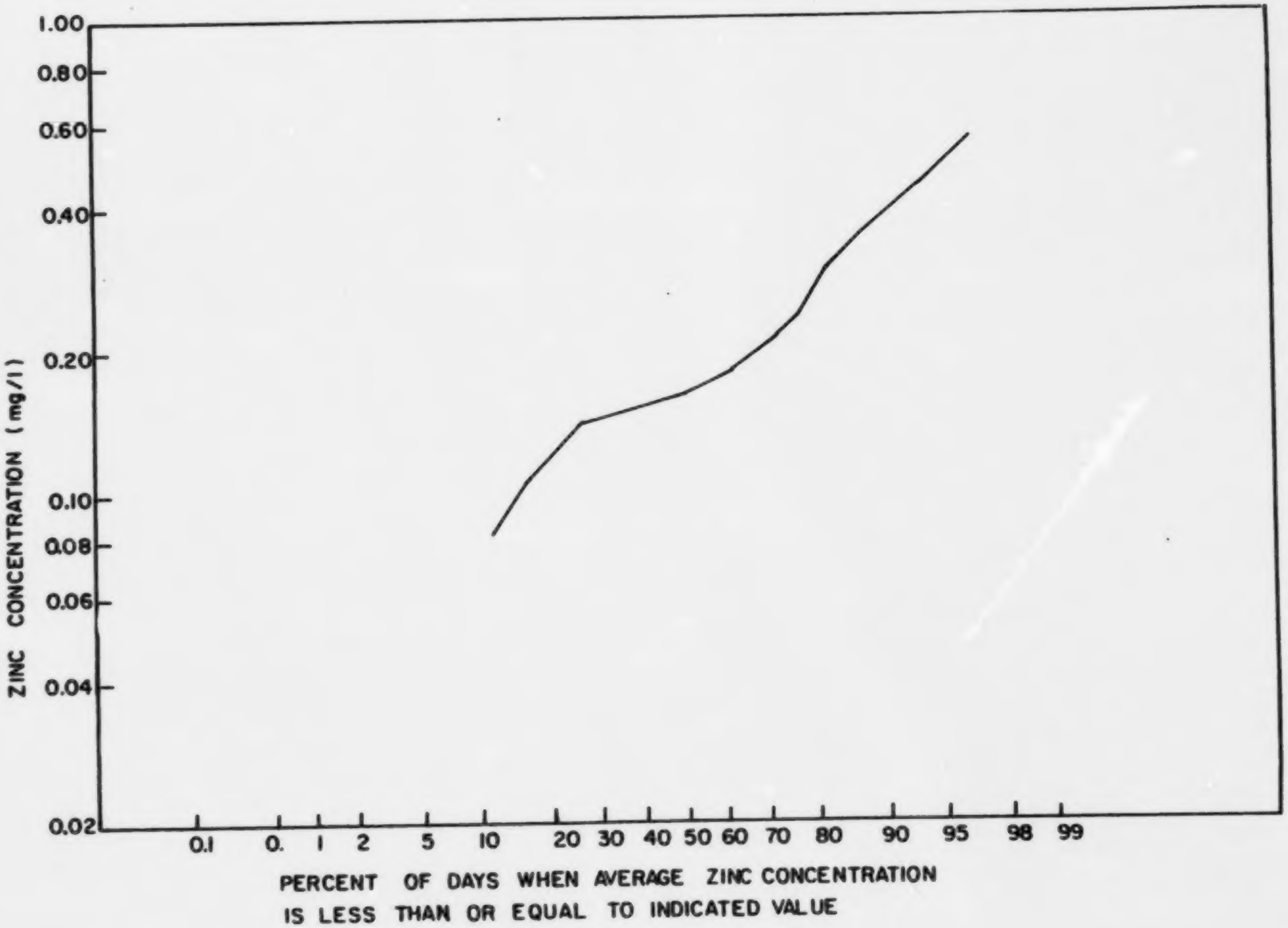


Figure 38. Effluent zinc frequency distribution.

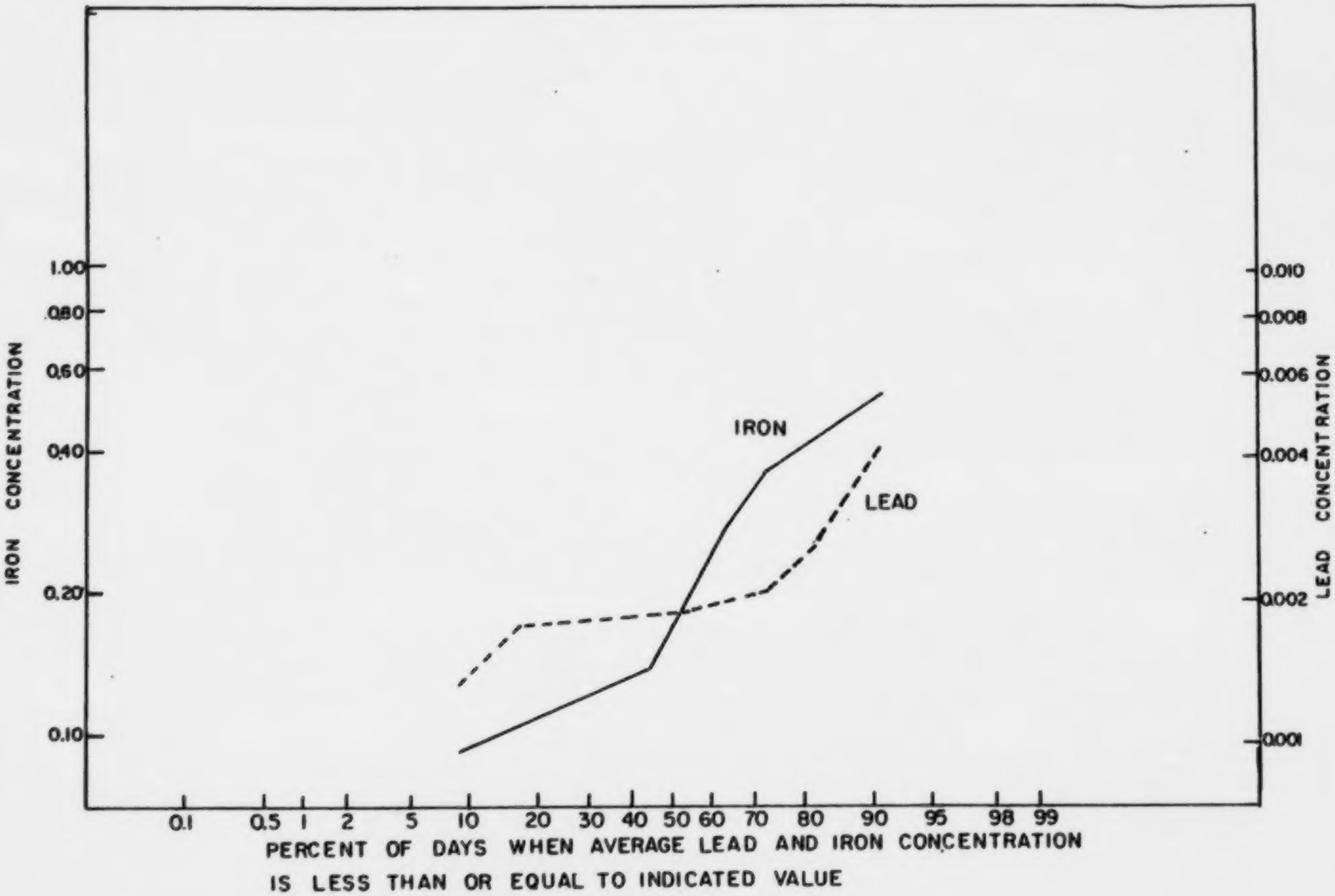


Figure 39. Effluent iron and lead frequency distribution.

SECTION 4

SOURCES AND FLOW OF HEAVY METALS AND CYANIDE IN THE KOKOMO, INDIANA, MUNICIPAL SEWER SYSTEM

INTRODUCTION

The objective of this study was to establish a protocol to assist communities in identifying, quantifying, and formulating regulatory policies for reduction of heavy metal and cyanide discharges to publicly owned treatment works (POTW) to the point that land disposal of sludge would be feasible. Several independent protocols had to be established or developed to accomplish this.

Establishment of a routine to obtain the most representative samples from likely sources (nonpoint, point, and street surface) was of primary importance. This involved determining: (1) sampling station locations, (2) metals and cyanide coverage, and (3) sampling frequencies. A second important area was development of an analytical method for metal and cyanide sample analysis. An EPA analytical procedure was modified for analysis of wastewater samples. The final concern was establishment of pretreatment strategy alternatives to reduce metal and cyanide inputs to the sewer network of a representative city to levels consistent with land disposal of digester sludge. The control strategy evolved during this study can be implemented by modifying present city ordinances which limit concentrations of metals and cyanide in industrial waste discharged to the sewer network. Guidelines and restrictions for various industrial categories not presently regulated must be promulgated.

Study Site Selection

The prototype community selected for this study was Kokomo, Indiana. It is a medium-sized city (42,000) with (from the sampling and analysis point of view) a manageably sized, combined sanitary and storm sewer treatment network that serves well-defined residential areas and a diverse industrial community. The industrial and commercial comlex of Kokomo includes operations such as electroplating, metal fabricating, automotive manufacture, chemical processing, and food processing.

Kokomo was chosen for the study for several reasons. Sewer system networks of large cities are so complex that they virtually defy definitive flow analysis and/or quantitative source identification. Smaller communities tend to have atypical residential-industrial flow compositions. Kokomo provided a wastewater flow mixture typical of an industrialized city (i.e., one that has neither an over-abundance nor a paucity of domestic or industrial sources discharging to the sewer network).

The treatment facility that serves the city of Kokomo is a newly renovated, 30 mgd activated sludge/multimedia gravity filter plant. Because of the contribution of substantial quantities of metals from various metal operations within the city, this particular POTW has experienced problems, not only with the treatment facility itself, but also with disposal of its digester sludge. This situation provided an excellent opportunity to investigate these problems.

The Kokomo sewer system is composed of six major trunklines serving the city and surrounding areas. Three of these trunklines are classified as purely residential, whereas the other three carry a combination of residential, commercial, and industrial wastewater. The city layout is such that the northern section (older part) is served by a combination storm and sanitary collection network, with overflows going to Wildcat Creek. The southern section of the city (new part) is served by a separate storm and sanitary collection system. Storm water is discharged to the Wildcat and Kokomo Creeks.

The metals originally chosen for this study were cadmium, chromium, copper, lead, mercury, and zinc. These particular metals were chosen because of their potential toxic effects on human health and the environment, primarily in respect to land disposal of sludge and to discharge of treated wastewater. Atomic absorption (AA)spectrophotometry was the method selected for trace metal determination because of the anticipated large number of samples and the ease and efficiency of analysis. As the project proceeded, mercury was excluded from the original list because of the extended amount of time needed for determination.

Total cyanide was also analyzed in this study, primarily because of its known association with trace metals in wastewater discharges from electroplating plants. The determination of total cyanide was carried out by a distillation-scrubber collection system and a pyridine-barbituric acid colorimetric procedure. Cyanide amenable to chlorination was also initially considered, but it was excluded because of the large number of samples expected and the necessity for rapid analyses. In addition, preliminary analysis revealed no measureable quantities of cyanides amenable to chlorination in the municipal and industrial wastewater. Only one industry treated their cyanide-based plating wastewater.

METHODS AND PROCEDURES

Sampling Protocol for Characterizing Metal and Cyanide Transport in Sewer Collection Systems

Trunkline sampling was conducted from April, 1978, to June, 1979, at twelve locations in the Kokomo sewer network (Figure 40). These locations were chosen to characterize metal and cyanide input to the treatment plant.

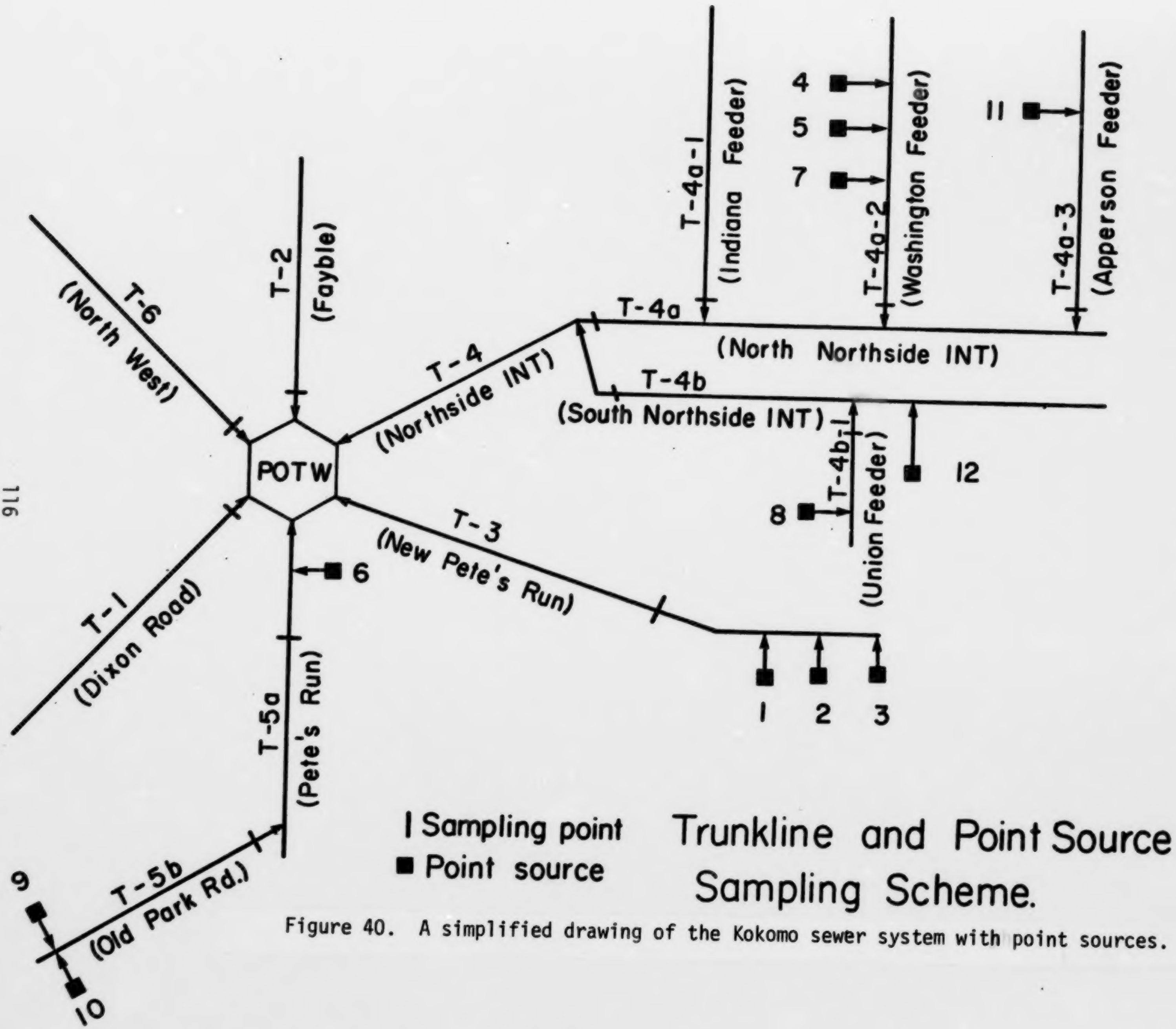

T-6
(North West)
T-2
(Fayble)
T-1
(Dixon Road)
POTW
T-4
(Northside INT)
T-4a
(North Northside INT)
T-4b
(South Northside INT)
T-4a-1
(Indiana Feeder)
T-4a-2
(Washington Feeder)
T-4a-3
(Apperson Feeder)
T-4b-1
(Union Feeder)
T-3
(New Pete's Run)
T-5a
(Pete's Run)
T-5b
(Old Park Rd.)
1
2
3
4
5
6
7
8
9
10
11
12
I Sampling point
■ Point source
Trunkline and Point Source Sampling Scheme.

Figure 40. A simplified drawing of the Kokomo sewer system with point sources.

Automatic sequential samplers (ISCO-1680)[1] and continuous flow recorders (Stevens F-68)[2] were used at each sampling location to measure metal and cyanide mass flow rates. Metal and cyanide samples were collected at each site in 500-ml acid-washed polyethylene bottles preserved with 2-ml 1:1 nitric acid for total metals and 2-ml 10N sodium hydroxide for total cyanides.

Samples were obtained for each trunkline at 2-hour intervals for three 24-hour periods. Sampling was conducted on a Monday through Thursday schedule, when feasible, to avoid any unusual fluctuations in flow or metal and cyanide discharge due to variations in industrial work schedules or increased residential activity during the weekend. Flow rates were determined using a combination of continuous flow recorders and sharp-crested weirs.

Sampling Site Selection--

One of the most critical steps in any sewer monitoring program is the selection of appropriate sampling site locations. An appropriate sampling site is one which provides: (1) easy accessibility to and from the site, (2) sufficient space to install sampling and flow recording equipment, (3) a suitable location with little or no slope and a straight section of the sewer to obtain accurate sampling and flow data, and (4) a critical point in the collection system for quantification of flow and pollutants.

Site selection during this study was difficult. Most problems involved insufficient space for sampling and flow recording equipment and/or sloped sewers with no straight sections in which proper weir construction was possible. An inordinate amount of time was spent searching for optimal sampling site locations. Figure 40 shows the final sampling sites used to obtain flow, metal, and cyanide data for the trunkline survey.

Selection of Flow Measuring Equipment--

The selection of the proper flow measuring equipment is perhaps the second most critical step in a sewer monitoring program. To select the appropriate type of flow device to measure a particular open channel flow, there are several considerations: (1) sample site conditions, (2) anticipated range of flow, (3) composition and type of waste to be measured, (4) allowable head loss, (5) required accuracy, and (6) site preparation cost.

With this information, it was determined that sharp-crested, V-notched, and Cipolletti weirs would be used for flow measurements. These weirs are simple to construct and easy to maintain on a short-term basis, and provide sufficient accuracy for flow determination. The primary disadvantages of weirs are the potentially high head loss and susceptibility to settling and accumulation of suspended particulates in the approach channel behind the upstream face. These factors can lead to inaccurate flow measurements and were regarded as negligible.

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[1] ISCO, Lincoln, Nebraska.

[2] Leupold and Stevens, Inc., Beaverton, Oregon.

The 90° V-notch weir was used to measure flows of less than 2 cfs (0.65 MGD). This weir was used primarily to monitor residential trunklines. The formula for flow with the 90° V-notch weir is:

$$Q = 2.49 H^{2.5}$$

where flow, Q, is in cfs, and H is the head measured in feet.

The Cipolletti weir was used to measure larger flows, such as those encountered in the trunklines which had a mixture of residential, commercial, and industrial wastewater. The flow formula for the Cipolletti weir is[3]:

$$Q = 3.37 LH^{1.5}$$

where

Q = discharge (cfs)

L = length of the weir opening at the base (feet)

H = measured head (feet)[3]

Weir Construction and Installation--

The manhole installation procedure for weir construction was in most cases similar for all sampling locations. The weir construction schedule, and therefore the time required to complete the trunkline sampling program, was greatly extended by the unusually difficult and long winters of 1978 and 1979. Extremely heavy snowfall and cold temperatures not only made construction and sampling virtually impossible during much of the winter season, but also contributed to a longer and heavier than usual spring thaw. The latter resulted in such high flows in trunklines due to street runoff and infiltration that weir construction and sampling were severely curtailed.

A profile of the sewer bottom was first determined by taking vertical measurements at intermittent distances across the sewer channel. A bulkhead, constructed out of 3/4-inch marine plywood, was then cut to fit this profile. An accurate V-notch or Cipolletti was constructed by first cutting the desired notch shape in the bulkhead and then mounting strips of 2-inch aluminum on the upstream side of the weir to fit the notch. The edges of the aluminum strips were positioned 1 inch away from the edges of the plywood to insure a knife-edge flow over the weir. Figure 41 shows a constructed Cipolletti weir ready for installation. The bulkhead was anchored in place by 2-by-4-inch bracing and Ramset[4] anchors. Special care was taken to insure proper horizontal and vertical alignment. The flow around the bulkhead was sealed by using hemp rope (okum) and putty. A porcelain-covered steel staff gauge was positioned upstream and located so that "0" on the gauge corresponded to the elevation of the weir crest (Figure 42).

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[3] Stevens Water Resources Data Book, 3rd ed., Beaverton, Oregon.

[4] Ramset Fastening Systems, Branford, Connecticut.

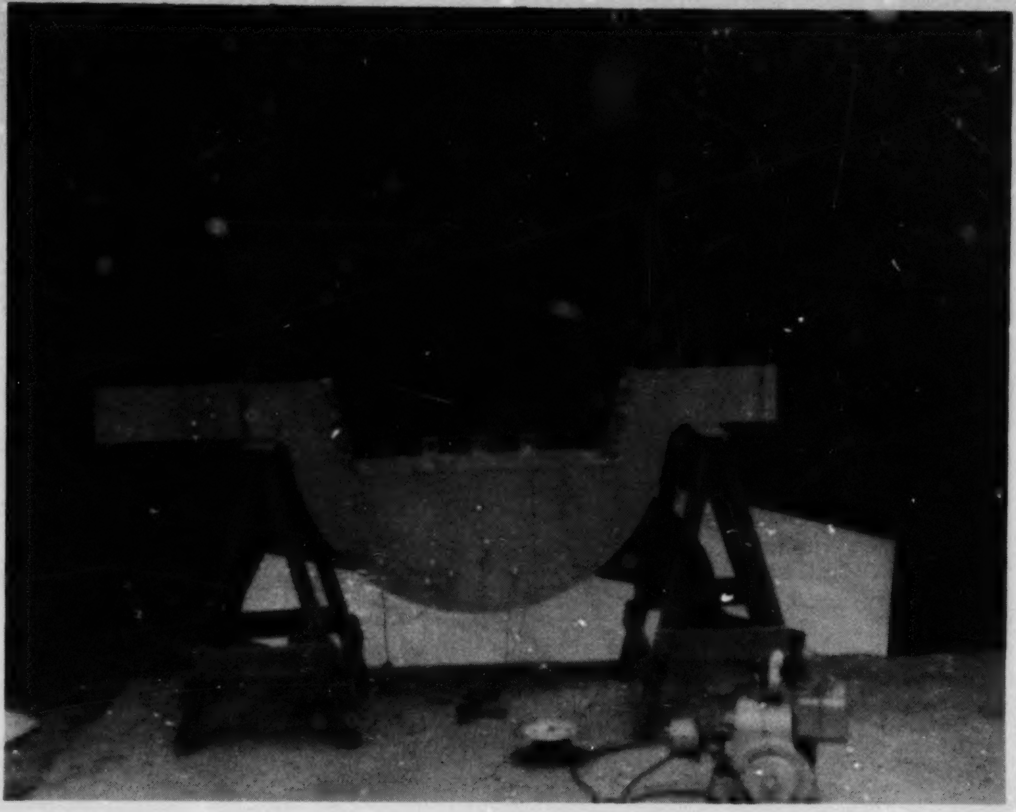

Figure 41. A constructed Cipolletti weir ready for installation.

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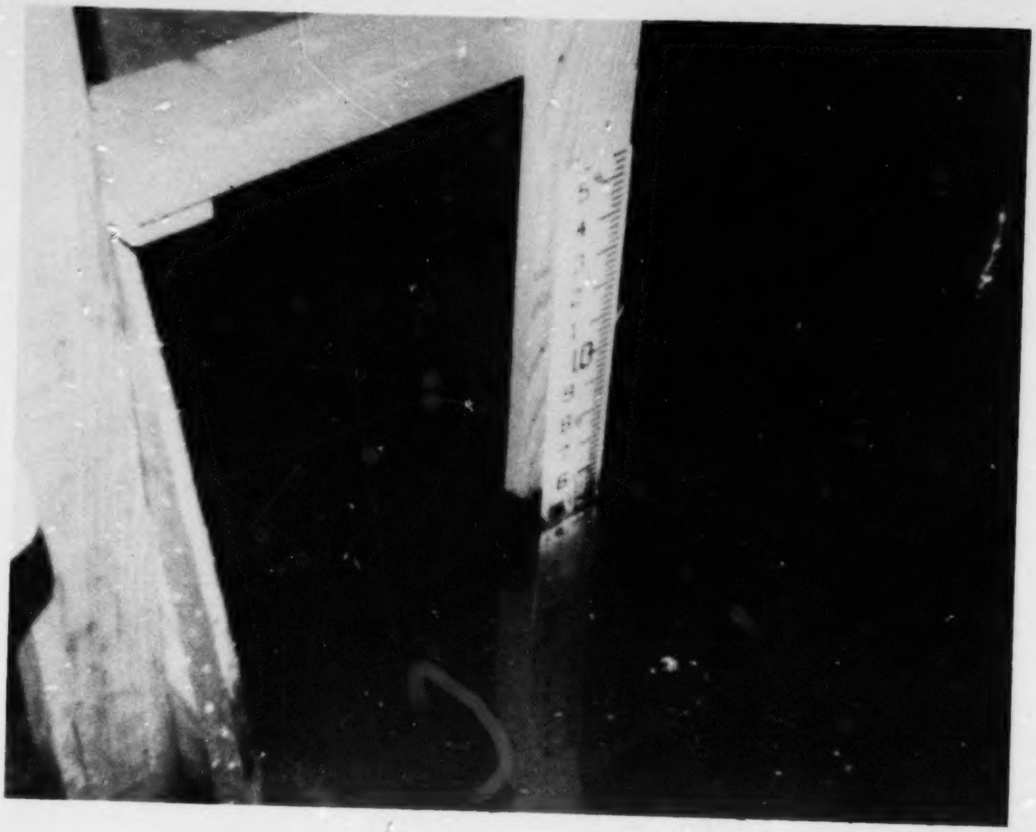

Figure 42. A porcelain-covered steel staff gauge positioned upstream and located so "0" on gauge corresponds to weir crest.

A mounting platform was then built for the flow recorder. A Stevens Type F level recorder was used for flow measurements. A 24-hour, mechanical clock was used to control the strip-chart flow recorder (Figure 43), and a stilling well was constructed, using 5-inch diameter plastic drainpipe. The well was positioned upstream from the weir plate.

A framework of 2 x 2 inch boards was constructed for the ISCO automatic sequential sampler (Figure 44). The sampler strainer was positioned in the middle section of the channel flow just upstream from the weir. Figures 45 and 46 illustrate the construction and installation of a Cipolletti weir. The flow recorder and sequential sampler were also installed and ready for operation.

Trunkline Monitoring Difficulties--

The adverse effect on trunkline sampling of unusually severe winter weather has been discussed. Submersion of weirs during frequent high flow periods prevented sampling for more than 120 days during the survey period, and high flow conditions also resulted in destruction of several installed weirs. Damage to one of the automatic samplers was also attributed to high flow conditions. Attempts to construct and install weirs and conduct a complete sampling program during the months of February, March, and April met with extraordinary difficulties.

Analytical Techniques for Determining Metal and Cyanide in Wastewater

Heavy Metals in Wastewater--

Samples for metal analysis were collected in 500-ml acid-washed polyethylene bottles containing 2 ml of 1:1 redistilled nitric acid. After collection, the samples were transported to the laboratory, logged in, and readied for sample preparation. Representative aliquots of 150 ml of homogeneous sample were transferred to a 200-ml Berzelius beaker and 5 ml of redistilled nitric acid was added. The samples were then placed on a hot plate and allowed to evaporate to dryness at low heat setting (no boiling should occur). More sample and nitric acid were added to the same beaker and the sample evaporated again.

This was done three times, using a total of approximately 400 ml of sample and 15 ml of redistilled nitric acid. Five ml of redistilled nitric acid were then added to the dried sample and the sample refluxed for 1 1/2 hours by placing a watchglass on top of the beaker and heating at a low setting. After 1 1/2 hours, 5 ml of hydrochloric acid (HCL, 37 percent) was added and the sample refluxed for another 1 1/2 hours. At the end of the second refluxing, the watchglass was removed and the sample allowed to evaporate to dryness.

Five ml of redistilled nitric acid were added and the sample heated at a low setting for a few minutes to solubilize the salt. Sample contents were then transferred to a 10-ml volumetric flask using a Pasteur pipette. The beaker was rinsed with double distilled water and the water used to bring the sample to the 10-ml volume.

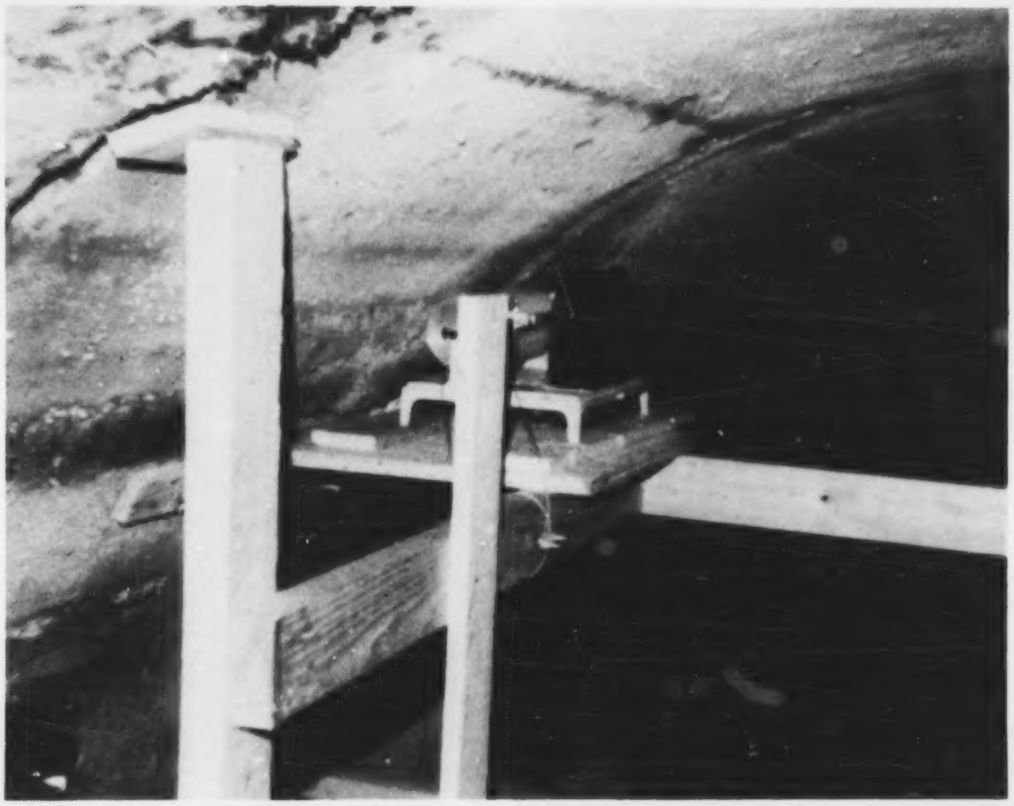

Figure 43. A 24-hour mechanical clock to control the strip-chart flow recorder.

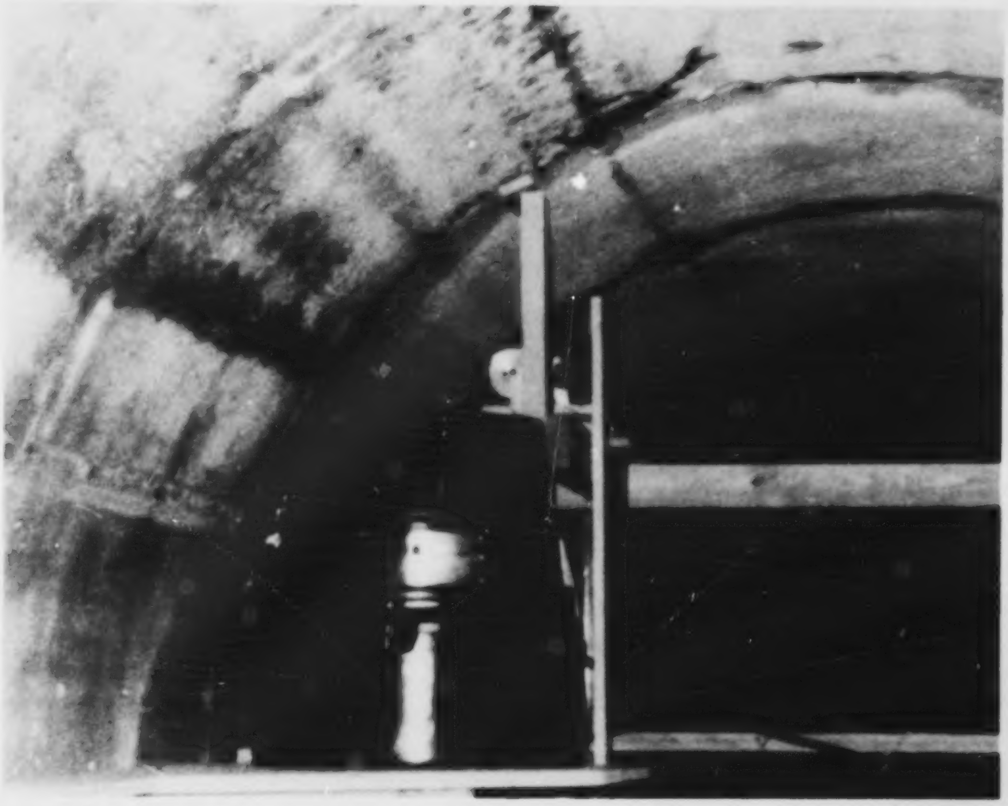

Figure 44. An ISCO automatic sequential sampler consisting of a 2-inch by 2-inch board framework.

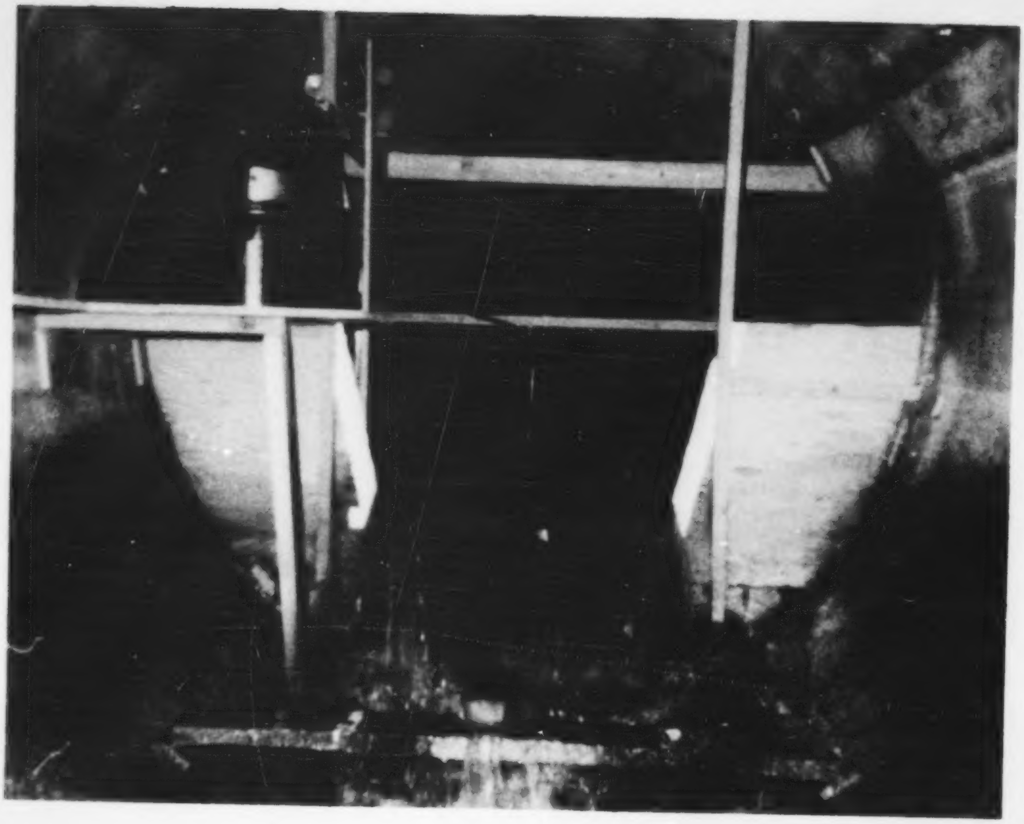

Figure 45. The construction of a Cipolletti weir.

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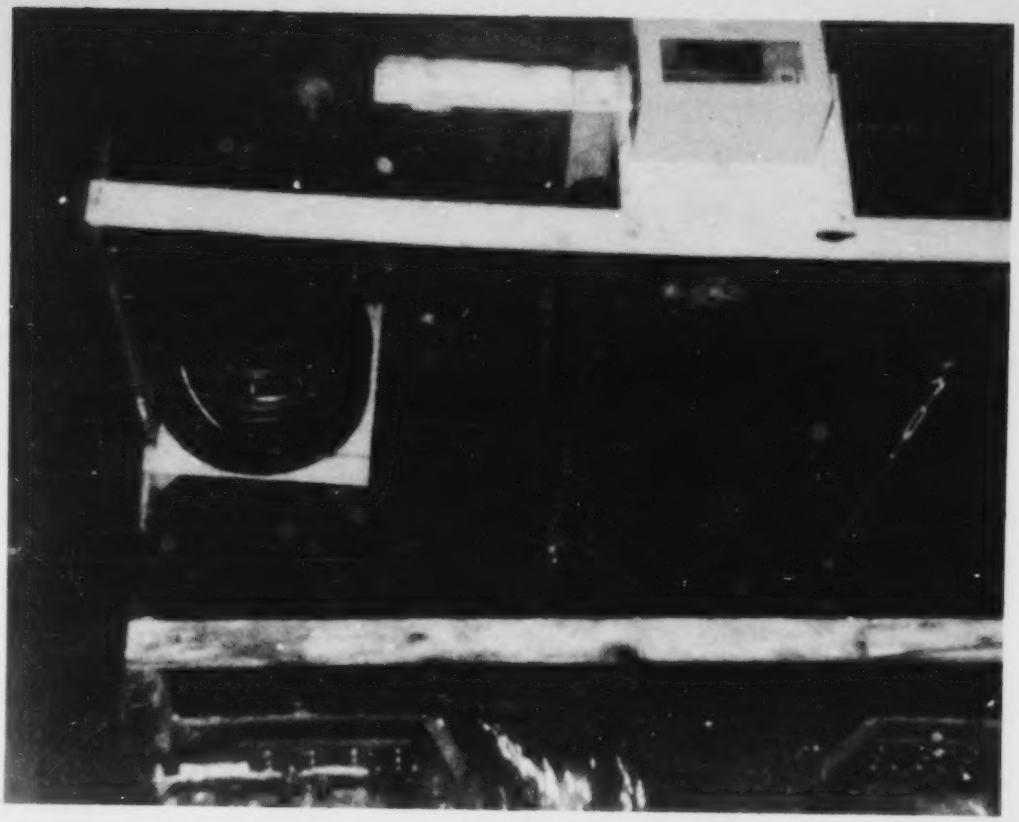

Figure 46. The installation of a Cipolletti weir.

Appropriate dilutions were made when necessary in 1:1 redistilled nitric acid. Samples were analyzed by atomic absorption spectrophotometry (Perkin-Elmer 5,000), using a deuterium arc background corrector. Appropriate standards were prepared for the metals by diluting stock solutions of cadmium, chromium, copper, lead, nickel, and zinc in 1:1 redistilled nitric acid and analyzing them in a manner similar to the field samples.

Accuracy and Precision of Metal Analysis--

The accuracy of metal analysis is mainly affected by systematic errors. These errors are not attributed to random fluctuations in analytical procedures. In this study, they included: (1) loss of metal during concentration, digestion, and transfer of samples to volumetric flasks, (2) matrix effects due to difference in viscosity of the sample solutions or to insolubility of metal in the matrix, and (3) background absorption due to dissolved salts.

Loss of metals during concentration, digestion, and transfer of samples is negligible. Table 56 shows the results of analysis of 12 "unknown" metal samples supplied by EPA to the laboratory. All samples were concentrated 25-fold, and were digested and transferred to volumetric flasks, using the same protocol as for sewage samples. The mean percentage recovery for these samples was 103.3 percent and the median 101.4 percent, indicating no detectable loss from digestion and transfer.

Interference in metal analysis as a result of matrix effects and by background absorption due to dissolved salts was measured by the "method of additions." Sewage samples were concentrated, digested, and analyzed before and after "spiking" with "unknown" metal samples supplied by EPA. The amount of unknown metal was calculated as the difference between the metal content of the sewage samples before and after spiking. As shown in Table 57, the mean percent recovery of unknown metal in the spiked samples was 96.5 percent and the median, 95.7 percent. Interference by matrix effects and background absorption resulted in a sytematic understatement of metal concentrations of approximately 4 percent.

A second group of errors which generally affect the precision of metal analysis are those which introduce random fluctuations into the analytical procedure. These errors, however, would not interfere with overall accuracy of metal analysis. Random errors included: (1) Errors introduced by improper homogenization of sewage samples prior to removal of measured aliquots for digestion. In most instances, this source of error was eliminated by analyzing the entire sewage sample collected (500 ml), (2) Errors introduced by inaccurate standard metal solutions. These errors were considered negligible since analysis of "unknown" metal samples supplied by EPA gave values close to "true" ones (see Table 58). (3) Instrumental errors introduced by short-term fluctuations in baseline absorption and longer-term drifts in absorption. These instrumental errors were responsible for most of the variabilility in the precision of analysis. Table 58 gives estimates of percent standard deviations for replicate sewage samples concentrated and digested before analysis. These estimates are for samples concentrated 40-fold during digestion, and do not account for systematic errors or errors in accuracy of the standards. As can be seen in Table 58, the percent standard

TABLE 56. RECOVERY OF UNKNOWN METAL SAMPLES SUPPLIED BY EPA[1]

Metal	mg/l	Percent Recovery[2]
Zinc	0.174	97.7
Zinc	0.030	124.7
Cadmium	0.073	94.6
Cadmium	0.023	100.0
Copper	0.102	100.0
Copper	0.073	100.3
Chrome	0.209	95.2
Chrome	0.154	103.9
Nickel	0.152	102.6
Nickel	0.045	108.4
Lead	0.352	102.3
Lead	0.298	110.0
		Mean - 103.3 Median - 101.4

---

[1] Samples were concentrated 25-fold prior to analysis.

[2] Average of three analyses.

TABLE 57. RECOVERY OF UNKNOWN METAL SAMPLES ADDED TO SEWAGE PRIOR TO DIGESTION AND CONCENTRATION*

Metal	Initial Metal Conc (mg/l)	Percent Recovery
Zinc	0.174	102.3
Zinc	0.030	103.7
Cadmium	0.073	91.2
Cadmium	0.023	93.5
Copper	0.102	94.4
Copper	0.073	97.7
Chrome	0.209	93.3
Chrome	0.154	91.6
Nickel	0.152	91.4
Nickel	0.045	97.1
Lead	0.352	100.6
Lead	0.298	101.7

Mean percent recovery - 96.5
Median percent recovery - 95.7

---

* Sewage samples spiked with unknowns were concentrated 40-fold prior to analyses. Regular sewage samples were also concentrated 40-fold prior to analyses. Unknown metal values were calculated by subtracting sewage sample values from spiked sewage sample values. Average of three samples.

TABLE 58. ESTIMATED PERCENT STANDARD DEVIATIONS AT NINE INITIAL METAL CONCENTRATIONS FOR REPLICATE SEWAGE SAMPLES CONCENTRATED 40-FOLD DURING DIGESTION*

	Initial (preconcentration) Metal Concentration (mg/l)								
	0.00025	0.00050	0.00100	0.00250	0.00500	0.01000	0.02500	0.05000	0.10000
Cadmium	79	41	22	15	10	4.5	4.0	4.0	4.0
Zinc	114	60	34	18	12	9.7	8.1	8.1	8.1
Chrome	<125	83	42	18	10	6.1	3.6	2.8	2.8
Copper	<125	<125	80	32	19	12	5.8	4.0	3.8
Nickel	<125	<125	<125	106	54	28	12	7.2	4.6
Lead	<125	<125	<125	<125	96	48	21	11	6.7

---

* Errors resulting from matrix effects, background effects, systematic loss of metals during concentration, or inaccurate standards would not be measured.

deviations for metal analyses tends to increase sharply with decreasing initial metal concentration. Table 59 lists the limits of detectability for the six metals analyzed. The limit of detectability was reached when the relative standard deviation was 50 percent.

Metal Values for Analysis of Replicate Samples--

To determine the precision of metal analysis in acid-digested concentrated sewage samples, four samples were analyzed five times and one sample was analyzed six times. The values for each sample for each analysis are shown in Table 60. For the sewage sample analyzed six times, the percent difference between three groups of two samples was computed and the average entered in Table 61. A comparison was also made of the absolute difference in metal value between three groups of two samples. The average value of the absolute difference was 0.13 mg/l for cadmium, 0.0 mg/l for chromium, 1.7 mg/l for nickel, 5 mg/l for lead, 6 mg/l for zinc, and 2 mg/l for copper (Table 61).

Cyanide in Wastewater

In general, the procedure used for cyanide determination was that described in the EPA publication, Methods for Chemical Analysis of Water and Wastes, 1974. The 500-ml cyanide samples were collected in acid-washed polyethylene bottles to which 2 ml of 10 N NaOH and 10 ml of 3 percent ascorbic acid in a vial had been added prior to collection. This preamendment method was carried out to minimize the destruction of cyanide due to delayed sample analysis (although sample analysis was performed within 24 hours in most cases) and to minimize the effect of interfering substances, such as oxidizing agents. Thus the NaOH maintained the samples at a pH of $\geq$12.0, while the ascorbic acid destroyed most of the oxidizing agents (bleaches) present at the time of sampling.

At the time of collection, the cyanide samples were kept cool by arranging them in the innermost circular configuration in the center of the sequential sampler into which ice had been placed. The ice maintained a cool environment (4° C) not only while the sampling was being carried out, but also while the samples were being transported back to the laboratory for analysis.

At the laboratory, each cyanide sample was logged in and tested for sulfides and additional oxidation agents by using lead acetate and potassium iodide-starch test papers, respectively. If these interfering compounds were present, further treatment was carried out according to the procedures outlined in the EPA methods.

Distillation of the samples was carried out in the following manner. A known amount (approximately 500 ml) of sample was placed into a 1 liter boiling flask. The boiling flask, condenser, and absorber (Milligan-Fisher scrubber with 250 ml of 0.2 N NaOH) were then connected to the vacuum source. A slow steady stream of air was maintained in the boiling flask by adjusting the vacuum source so that approximately one bubble of air per second entered the absorber through the absorber inlet tube.

TABLE 59. LIMIT OF DETECTABILITY FOR HEAVY METALS

Metal	Limit of Detectability (mg/l)
Cadmium	0.0004
Zinc	0.0006
Chrome	0.0008
Copper	0.002
Nickel	0.005
Lead	0.010

The limit of detectability was reached when the relative standard deviation was 50 percent. Values are for initial metal concentrations in samples concentrated 40-fold during digestion.

TABLE 60. METAL VALUES FOR ANALYSIS OF REPLICATE SAMPLES

		Metal (mg/l)					
Sample	Conc. Factor	Copper	Zinc	Nickel	Lead	Cadmium	Chrome
Sewage	40.15	0.063	0.094	0.003	0.021	0.0003	0.056
Used	40.15	0.068	0.092	0.005	0.014	0.0004	0.058
For	40.15	0.068	0.103	0.006	0.014	0.0003	0.058
EPA	40.15	0.068	0.114	0.006	0.007	0.0001	0.058
"Unknown"	40.15	0.068	0.089	0.007	0.017	0.0003	0.056
Analysis	40.15	0.067	0.093	0.004	0.017	0.0004	0.056
Average		0.067	0.079	0.005	0.015	0.00028	0.057
Std Dev		0.0021	0.0094	0.0014	0.0047	0.000098	0.0011
% Std Dev		3.17	9.7	28	32	35	1.9

TABLE 61. METAL CONCENTRATIONS FROM ANALYSIS OF DUPLICATE SAMPLES

	Metal					
	Cadmium	Chromium	Nickel	Lead	Zinc	Copper
Average percent difference between three groups of 2 samples for sewage samples analyzed 6 times	66	1	47	50	5	3
Average difference between three groups of 2 samples for sewage samples analyzed 6 times (mg/l)	0.00013	0	0.0017	0.005	0.006	0.002

After air flow adjustment, 20 ml of concentrated sulfuric acid was slowly added to the boiling flask through the separatory funnel. The funnel was rinsed with distilled water and the sample and acid allowed to mix with the air flow for 3 to 5 minutes. An additional 10 ml of 3 percent ascorbic acid were added to the sample and the separatory funnel rinsed with distilled water. Finally, 10 ml of cuprous chloride ($Cu_2 Cl_2$) reagent were added to the sample and the separatory funnel rinsed with distilled water again. The contents of the flask were then heated to boiling, being careful to prevent the contents from backing up and overflowing out of the air inlet tube. The samples were distilled-refluxed for 1 hour. The heat was then turned off and the air flow allowed to continue for an additional 15 to 20 minutes for cool-down. After cool-down, the boiling flask, absorber, and vacuum source were disconnected.

The solution in the absorber was transferred into a volumetric flask and brought to volume with distilled water washings from the absorber inlet tube. A 25-ml aliquot of this solution was transferred to a 50-ml volumetric flask and the cyanide concentration determined colorimetrically. The pyridine-barbituric colorimetric method used was similar to that outlined in the EPA procedure, with the exception that 7.5 ml of sodium phosphate solution, 1 ml of Chloramine T solution, and 2.5 ml of pyridine-barbituric solution were used. Distilled water was used to bring the sample to volume. After a color-developing time of 8 minutes, the sample absorbance was read on a spectrophotometer (Perkin-Elmer, Coleman 44) at a 578 nm wavelength within 15 minutes. A standard cyanide curve was prepared by diluting suitable volumes of standard solution to 500.0 ml with distilled water and plotting absorbance of standard versus cyanide concentration.

The percent recovery for this method is presented in Table 62. The cyanide recovery was adequate down to 0.2 mg/l, where it decreased sharply.

TABLE 62. RECOVERY OF CYANIDE AS A FUNCTION OF INITIAL CONCENTRATION WITH DISTILLATION COLORIMETRIC METHOD

Concentration (mg/l)	Percent Recovery
0.50	100.0
0.40	98.3
0.30	91.0
0.20	88.3
0.10	62.6

The precision of this procedure is presented in Table 63. The values shown as relative standard deviation represent three samples, each analyzed four times. The precision of the method was adequate down to 0.1 mg/l concentration, where it also dropped off dramatically. Sensitivity of the procedure was 0.02 mg/l.

TABLE 63. PRECISION OF THE CYANIDE DISTILLATION COLORIMETRIC METHOD

Concentration (mg/l)	Percent Relative Standard Deviation
0.40	7.4
0.30	9.1
0.20	21.2
0.10	20.3

POINT SOURCE TESTING

The quantification of metal and cyanide input from specific industries to the Kokomo sewage treatment plant yielded much information. The point source survey of Kokomo industries provided a data base which operators of other publicly owned treatment works (POTW) may utilize to estimate metal and cyanide input to their particular collection systems. Where treatment was practiced, sampling raw and treated wastes of point sources discharging to the Kokomo system provides operators of other sewage treatment plants with information on degrees of pollutant removal which are feasible for the types of industries surveyed here. This information enables other POTW operators to determine technologically feasible limits of control for industries they serve so that a reduction in heavy metal and cyanide levels in sludge would make land disposal a feasible alternative.

Twelve known point sources of heavy metals and cyanide identified by Standard Industrial Classifications (SIC) were sampled in this study over a 3-month period in 1979 (see Figure 40). Flow data from these point sources were obtained from flow meters and/or city water meters available at each one. In one case, a pair of V-notch weirs with a recording depth-of-flow indicator (Stevens flow recorder and float) was employed to measure flow above and below the point of discharge.

Waste streams were sampled at two hour intervals for three consecutive 24 hour periods (days). Metal and cyanide samples were collected using an automatic sequential sampler (ISCO). The treatment and analysis of these samples are described elsewhere in this report. Table 64 lists the point sources and identifies each one by a brief description of its industrial function.

Point Source 1

Point Source 1 is a major manufacturer of automatic transmissions and aluminum die castings for the automotive industry. Its transmission and casting facilities are the two largest operations of their kind in the world. Over 9,000 transmissions are produced daily and nearly 2.5 million are manufactured annually. The Kokomo casting plant die casts some 122 different parts, including transmission cases, extension valve bodies, and transfer plates.

Effluent wastes from the transmission plant and die cast plant are collected in a common receiving pit for solids settling. Overflow from the receiving pits is transferred to one of four batch tanks (one tank is currently being used as a oil/water separator). Underflow (solids) is transported to an approved landfill for ultimate disposal, and each batch tank is then treated with acid, caustic, alum, polymer coagulant aid, and polymer emulsion breaker, depending upon treatment required. Treated effluent from the batch tank is discharged to the Kokomo sanitation network. Solids that settle from the batch tank processes are returned to the receiving pit for ultimate reprocessing and disposal. Oil from the oil-water separator and skimmings from the three other batch tanks are sent through a series of skim oil holding tanks for heating (140° F) and acid addition to enhance decanting.

TABLE 64. LIST OF POINT SOURCES IN KOKOMO BY INDUSTRIAL PRODUCT OR SERVICE

Point Source	Product
1	Aluminuum die casting Automatic transmissions
2	Electroplating
3	Electronic semiconductor components
4	Electroplating Metal products
5	Electroplating
6	High and low carbon Wire products
7	Galvanizing
8	Aluminum products
9	Nickel-, cobalt-, and iron-based alloys Melting, forging, hot rolling
10	Nickel-, cobalt-, and iron-based alloys Cold rolling and fabrication
11	Laundry services
12	Printing services

Decanted water is either transferred back to the receiving pit or neutralized with caustic (3 percent) and blended in with the batch treatment effluent discharged to the city sewer system. Oil from the holding tanks is filtered to strip out remaining solids, and spent filter cake from the filter is transported to a landfill for approved disposal. Ultimate separation of oil and water occurs in a final tank before oil reclamation. Decant from the reclaimed oil tank is discharged to the city sewer system. The final effluent from Point Source 1 is presented in Table 65.

Point Source 2

Point Source 2 primarily conducts circuit board plating operations and also does some soldering and assembling of radio components. One of the main radio components constructed at this location is bridge audio work. The

TABLE 65. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 1 TO NEW PETE'S RUN (T-3) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.496	0.006	0.034	0.28	0.14	3.02	0.20	<0.42
Day 2	0.379	0.004	0.018	0.16	0.088	1.32	0.16	<0.33
Day 3	0.446	0.004	0.048	0.21	0.080	1.40	0.44	<0.38
Mean	0.440	0.005	0.033	0.22	0.10	1.91	0.27	<0.38
S.D.	0.059	0.001	0.015	0.06	0.03	0.96	0.15	0.05

treatment facilities at Point Source 2 are primarily intended to treat electroplating effluents.

All process waste from the circuit board plating operations goes to the treatment facilities, where two types of waste are treated: metal-bearing wastes (general waste) and diluted concentrations of cyanide-bearing wastes (cyanide waste). Treatment of each is of the batch process type, in that the waste liquid is treated, held, and monitored for quality before discharge (Figure 47).

General waste treatment consists of pH adjustment and precipitation of heavy metals, such as hydroxides. Chemical reactants for pH control are sodium hydroxide to raise the pH and sulfuric acid to lower it. A pH of 9.0 is maintained in the general treatment tank to enhance settling. The general waste treatment process includes provisions for treating cross-contamination within the plant collection system of cyanide wastes. There are two general waste tanks holding 0.93 million gallons each.

Cyanide waste treatment consists of two-phase destruction of cyanide to carbon dioxide and nitrogen gases. This process adds sodium hydroxide to raise the pH to 10.5, while adding chlorine gas in the recirculation line. The pH is reduced to 8.5 and chlorine added until cyanide destruction is complete. There are two cyanide waste tanks holding 0.18 million gallons each.

After treatment, effluent from the general waste and cyanide waste tanks is pumped into a waste blending tank (30,000 gal). Provisions are incorporated to add either additional caustic or acid for pH trimming. The liquids flow from the blend tank into a solids contact reactor clarifier where a coagulant aid is added to enhance flocculation and particle agglomeration. The overflow from the clarifier flows into the Kokomo sewer system. The underflow from the clarifier is next pumped into two sludge thickeners, which operate either in parallel or in series for optimum dewatering and sludge concentration. Any overflow from the sludge thickeners is returned to the general waste system. The thickened sludge is pumped to a sludge conditioning

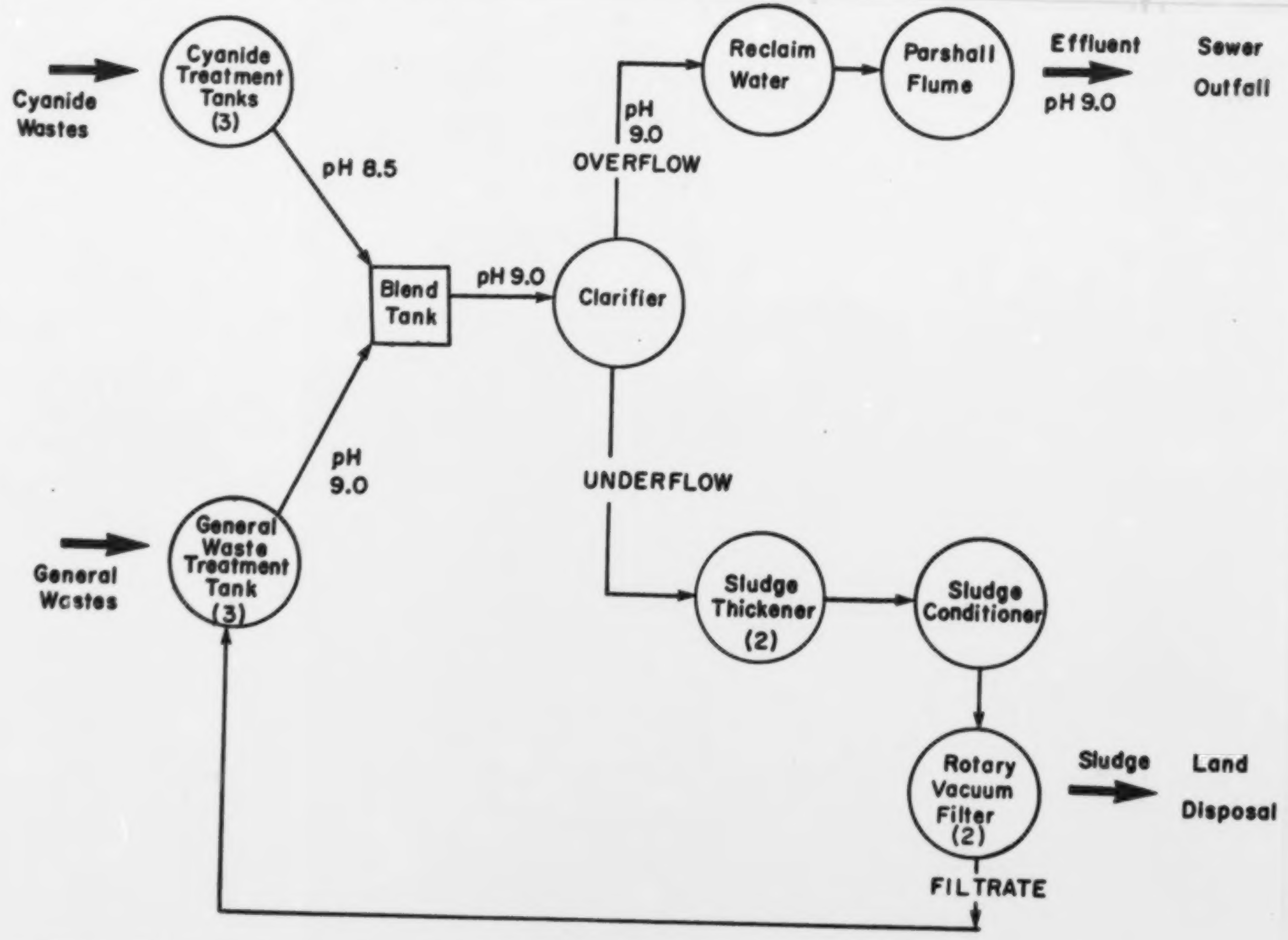
Cyanide Wastes
Cyanide Treatment Tanks (3)
pH 8.5
General Wastes
General Waste Treatment Tank (3)
pH 9.0
Blend Tank
pH 9.0
Clarifier
pH 9.0
OVERFLOW
Reclaim Water
Parshall Flume
Effluent
pH 9.0
Sewer Outfall
UNDERFLOW
Sludge Thickener (2)
Sludge Conditioner
Rotary Vacuum Filter (2)
FILTRATE
Sludge
Land Disposal

Figure 47. Treatment system for Point Source 2.

TYPING GUIDE SHEET

tank where additional mixing takes place and filter aid (prefilter chemical) is added if necessary. The conditioned sludge flows by gravity to one of two rotary vacuum filters for final dewatering. The filtrate liquid is returned to the general waste system, and solids are collected for hauling to an approved landfill for ultimate disposal. The effluent of Point Source 2 is presented in Table 66.

TABLE 66. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 2 TO NEW PETE'S RUN (T-3) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cd	Ni	Pb	Zn	Cu	CN-
Day 1	0.720	0.19	0.11	0.19	<0.078	1.15	6.74	<0.99
Day 2	0.270	0.044	0.032	0.034	<0.027	0.26	2.16	<0.25
Day 3	0.324	0.054	0.034	0.034	<0.027	0.38	2..54	<0.25
Mean	0.438	0.096	0.058	0.086	0.020	0.60	3.81	<0.51
S.D.	0.246	0.082	0.045	0.090	0.029	0.49	2.54	0.42

Point Source 3

Point Source 3 manufactures various radios and radio parts, with a long line of semiconductor components. Other products include digital controls, silicon rectifiers, and microelectronic voltage regulators. Some plating of radio parts is also conducted at this location. The wastewater treatment facilities installed at Point Source 3 are primarily intended to treat electronic semiconductor manufacturing and electroplating effluents.

All process waste from the semiconductor manufacturing and electroplating operations goes to the treatment facilities. At this treatment plant, five basic types of waste are treated: (1) metal-bearing waste (general waste); (2) dilute concentration of cyanide-bearing waste (cyanide waste); (3) dilute hydrofluoric acid; (4) dilute nickel waste; and (5) hexavalent chromium-plating rinse (see Figure 48).

General waste treatment consists of pH adjustment and precipitation of heavy metals as hydroxides. Chemical reactants for pH control are lime (calcium hydroxide) with sodium hydroxide as an emergency backup to raise the pH and sulfuric acid to lower the pH. A pH of 9.0 is maintained in the general waste tanks to enhance settling. The general waste treatment process includes provisions for treating cross-contamination within the plant collection system of cyanide. There are three metal waste treatment tanks, holding 1.4 million gallons each.

Cyanide waste treatment consists of a two-phase destruction of cyanide to carbon dioxide and nitrogen gas. This is accomplished by the addition of lime to raise the pH to 10.5, while adding chlorine gas in the recirculation line. Sodium hydroxide is used as a backup for the lime. The pH is reduced to 8.5

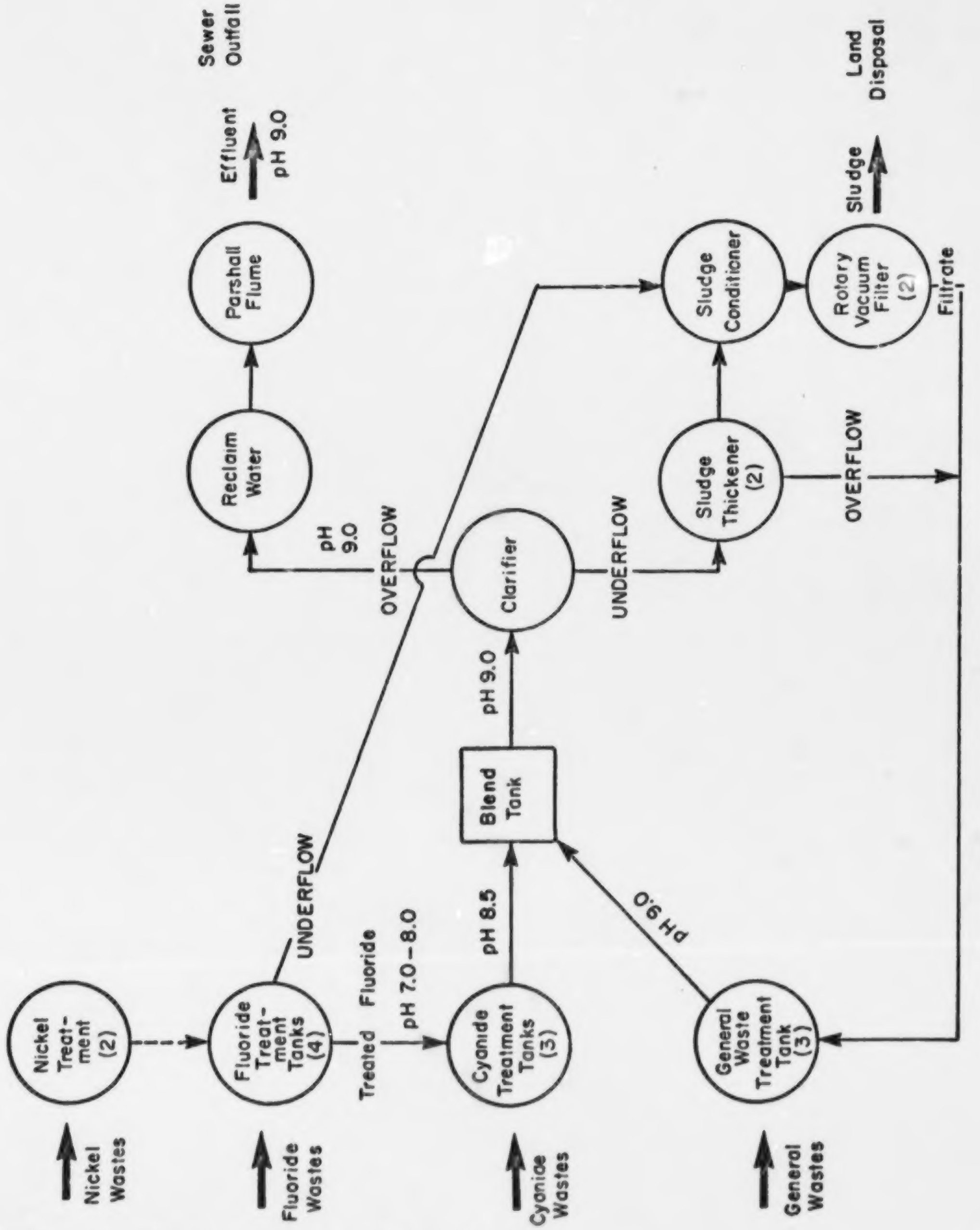
Nickel Wastes
Nickel Treat-ment (2)
Fluoride Wastes
Fluoride Treat-ment Tanks (4)
UNDERFLOW
Treated Fluoride
pH 7.0–8.0
Cyanide Wastes
Cyanide Treatment Tanks (3)
pH 8.5
General Wastes
General Waste Treatment Tank (3)
pH 9.0
Blend Tank
pH 9.0
Clarifier
OVERFLOW
pH 9.0
UNDERFLOW
Reclaim Water
Parshall Flume
Effluent
pH 9.0
Sewer Outfall
Sludge Thickener (2)
OVERFLOW
Sludge Conditioner
Rotary Vacuum Filter (2)
Filtrate
Sludge
Land Disposal

Figure 48. Treatment system for Point Source 3.

and chlorine is added until cyanide destruction is complete. There are three cyanide waste treatment tanks, each holding 0.19 million gallons.

Fluoride treatment consists of pH adjustment, using lime for acid neutralization and precipitation of calcium fluoride. There are four fluoride treatment tanks, each having a volume capacity of 7,000 gallons. Each tank is equipped with decant valves to drain off the clear treated liquid. The clear decant is transferred to the cyanide treatment tanks for further treatment. The densified underflow (calcium fluoride sludge) is pumped to the sludge conditioning tank for preparation for filtering. The calcium fluoride is settled by gravity within 24 hours, or the settling can be improved by addition of polyelectrolyte polymers.

Nickel treatment consists of pH adjustment for precipitation of nickel hydroxide. A backup system of nickel treatment consists of addition of sodium polysulfide with precipitation of nickel sulfide. The treated nickel is either transferred to the sludge conditioning tank, or transferred to the other fluoride treatment tanks to blend with calcium fluoride sludge. There are two 750 gallon storage tanks for nickel wastes. Nickel treatment is performed in the fluoride treatment tanks after being transferred from the storage tanks. At the present time, however, nickel operations are inactive.

Chromium treatment is a self-contained batch process remotely located from the treatment facility. The process consists of collecting the small volume of plating rinse water in a treatment pit. Sulfuric acid and sulfur dioxide are added to maintain a pH below 3.0 while providing an electron donor material: sulfur at plus four valence. Chromium is continuously reduced from the hexavalent to the trivalent form. Circulating pumps recirculate the treatment liquid back to the rinse tank.

After treatment, liquid from the general waste, cyanide waste, and fluoride and nickel tanks is transferred to a waste blending tank into a contact reaction well clarifier, where coagulant is added to enhance flocculation and particle agglomeration. The overflow goes from the clarifier to the Kokomo sewer system. The underflow from the clarifier is pumped into two sludge thickeners which can operate either in parallel or in series for optimum dewatering and sludge concentration. Any overflow from the sludge thickeners is returned to the system for further treatment. The thickened sludge is pumped into a sludge conditioning tank (1,500 gallons) where further mixing occurs, and filter aid or other suitable prefilter chemicals are added if necessary. The calcium fluoride and nickel hydroxide sludges are combined with other sludges in the tank, and the conditioned sludge flows by gravity to one of two 250-square-foot rotary vacuum filters for final dewatering. The filtrate liquid is returned to the process for further treatment, and solids are collected for hauling to an approved landfill for ultimate disposal. The final effluent from Point Source 3 is presented in Table 67.

Point Source 4

Point Source 4 manufactures major products for the automotive, construction, and agricultural industries. The company's products include hydraulic piston rods for farm and commercial applications, hydraulic valves

TABLE 67. DAILY DISCHARGE OF METAL AND CYANIDE FROM POINT SOURCE 3 TO NEW PETE'S RUN (T-3) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	1.549	0.71	0.13	0.59	<0.13	17.98	3.49	<1.33
Day 2	1.539	0.65	0.12	0.65	<0.13	44.12	5.01	2.19
Day 3	1.944	0.75	0.15	1.01	<0.47	30.60	5.04	≤4.46
Mean	1.677	0.70	0.13	0.75	<0.28	30.90	4.51	≤3.55
S.D.	0.231	0.05	0.02	0.23	0.20	13.11	0.89	1.67

and cylinders for agricultural and construction equipment industries, stamped metal assemblies for air-ride systems for trucking industries, and recreational vehicles. Noncyanide zinc and hard chrome plating are also done at the plant.

Treatment facilities include a 600-gallon chromium reduction tank equipped with pH controls, sulfuric acid, and sodium bisulfite feed equipment and mixer, two 9,000-gallon batch neutralization tanks equipped with pH controls, two mixers and caustic feed equipment, and a 50-gallon per minute continuous belt vacuum filtration unit (Figure 49). The anticipated effluent characteristics for both total chromium and zinc are <1.0 mg/l. These values represent a metal removal efficiency of >99 percent for total chromium and >98 percent for zinc. Point Source 4 discharge to the Kokomo sanitary sewage system is presented in Table 68. At the time of sampling, the chromium pretreatment unit was constructed but not in operation.

Point Source 5

Point Source 5 specializes in plating various manufactured products. It provides services for both rack and barrel plating and finishes, ranging from cadmium, hard chromium, zinc, copper, nickel, silver, and tin plating. Point Source 5 plating operations include copper bath (150 gal); zinc bath (2,100 gal); nickel bath (4,400 gal); chromium bath (3,100 gal); cadmium bath (1,100 gal); silver bath (200 gal); alkaline tin bath (350 gal); and an acid tin bath (150 gal). The copper, zinc, cadmium, and silver are also cyanide operations.

No treatment of metal and cyanide wastewater is presently practiced. Effluents from plating operations are discharged directly to the Kokomo sewer network, and acid and alkali baths are dumped to the plant waste stream once every two weeks. The effluent from Point Source 5 is presented in Table 69.

Point Source 6

Point Source 6 is a manufacturer of high and low carbon steel wire for industrial and commercial use. Its products also include nails, various wire

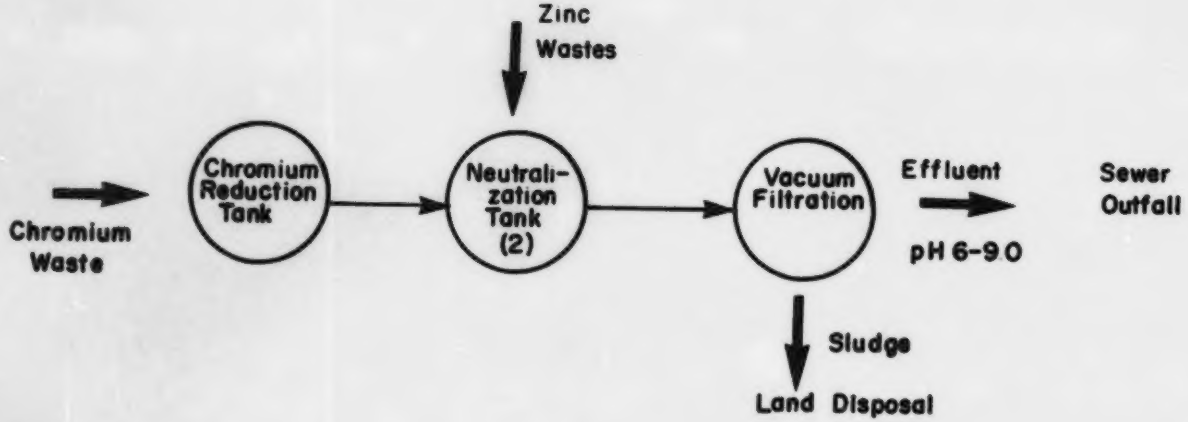
Zinc Wastes
Chromium Waste
Chromium Reduction Tank
Neutralization Tank (2)
Vacuum Filtration
Effluent
pH 6-9.0
Sewer Outfall
Sludge
Land Disposal

Figure 49. Treatment system for Point Source 4.

TABLE 68. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 4 TO WASHINGTON FEEDER (T-4a-2) AND SUBSEQUENTLY TO THE NORTH NORTHSIDE INTERCEPTOR (T-4a)*

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN-
Day 1	0.095	<0.002	≤7.75	≤0.033	≤0.035	20.82	0.17	<0.079
Day 2	0.092	≤0.002	6.24	≤0.026	0.054	32.02	0.094	<0.077
Day 3	0.093	<0.002	11.97	≤0.008	0.041	1.17	0.096	<0.078
Mean	0.092	<0.002	<8.65	≤0.023	≤0.043	18.00	0.12	<0.078
S.D.	0.015	0.000	2.97	0.013	0.009	15.63	0.04	0.001

TABLE 69. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 5 TO THE WASHINGTON FEEDER (T-4a-2) AND THE NORTH NORTHSIDE INTERCEPTOR (T-4a)

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN-
Day 1	0.235	0.41	39.12	6.21	0.067	1.10	0.67	≤0.45
Day 2	0.213	0.36	79.93	3.45	0.067	1.48	0.61	0.43
Day 3	0.264	0.94	130.36	4.69	0.51	3.77	1.63	3.72
Mean	0.237	0.57	83.23	4.78	0.21	2.12	0.97	≤1.53
S.D.	0.026	0.32	45.70	1.38	0.26	1.44	0.57	1.89

products, fencing, and other galvanized material for farm, industrial, and domestic use.

Wastes with pollution potential emanate from (1) steel melting, (2) primary rolling, (3) secondary rolling, (4) pickling, and (5) coating facilities. The contaminants include oils, solids, chemicals, metals, acids, and elevated temperatures which must be treated. The waste treatment system of Point Source 6 includes both nonchemical (mechanical) and chemical treatment for removing contaminants from the mill cooling and process water. The system is given in Figure 50.

The nonchemical cooling water treatment system consists of two centrifugal separators to remove the large suspended solids and a high rate pressure sand filter to remove the smaller suspended particles. The "clean" water from the sand filter is then recycled for other plant use. The underflow from centrifugal separators is pumped to a solids settling and

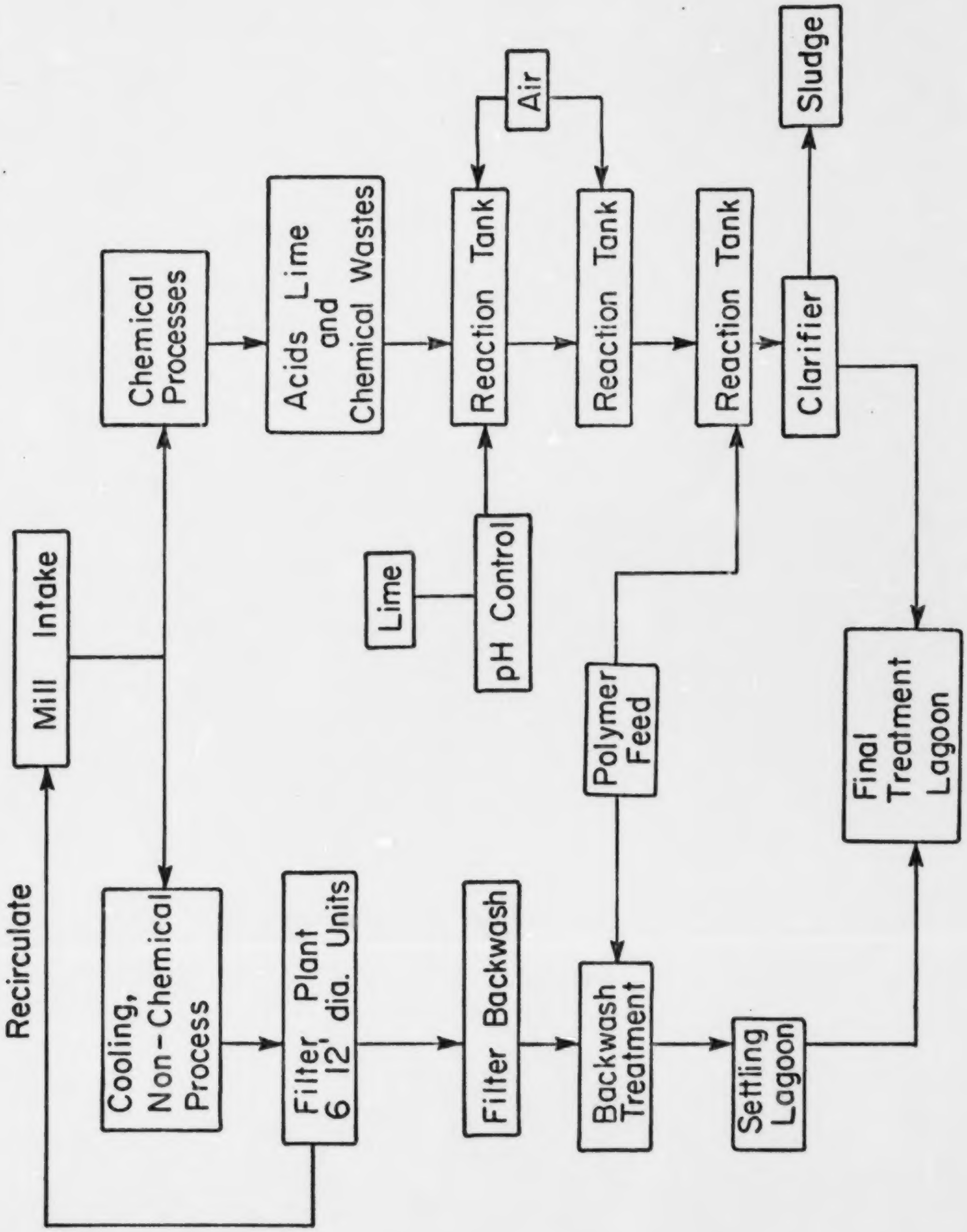
Mill Intake
Recirculate
Chemical Processes
Acids Lime and Chemical Wastes
Reaction Tank
Air
Reaction Tank
Reaction Tank
Clarifier
Sludge
Lime
pH Control
Polymer Feed
Cooling, Non-Chemical Process
Filter Plant 6 12' dia. Units
Filter Backwash
Backwash Treatment
Settling Lagoon
Final Treatment Lagoon

Figure 50. Treatment system for Point Source 6

reclamation lagoon. Effluent from this lagoon is then transferred to a terminal lagoon.

Chemical treatment consists of an acid neutralization facility to treat (1) all concentrated chemical and acid wastes emanating from the mill, (2) selected chemical and acid rinses, and (3) backlogged wastes stored in the lagoon system. The basic facility consists of a lime neutralization process, two 110-foot diameter clarifier/thickeners, and two vacuum filters for solids removal. Overflow from the clarifier/thickeners is pumped directly to the terminal lagoon, while underflow from the clarifier/thickeners is transferred to vacuum filters. The resultant filter cake from the vacuum filters is transported to a suitable landfill for ultimate disposal. The final effluent from Point Source 6 is presented in Table 70.

Point Source 7

Point Source 7 conducts metal-finishing operations. The major product from this industry is the "hot dipped" galvanizing of woven chainlink fencing. No special treatment facilities exist at this location except the batch type neutralization of etching acid. Discharge wastewater consists of rinse from the alkaline process, quench water from the chainlink fencing process, and acid drippings from the etching process. Final effluent from Point Source 7 is presented in Table 71.

Point Source 8

Point Source 8 manufactures architectural aluminum entrances for all types of commercial buildings. It also manufactures extruded aluminum storefront and curtain wall systems for the commercial construction market. The prime functions of this plant include aluminum extrusion, anodizing, and fabrication.

Wastewater discharged to the Kokomo sewage network consists of de-ionizer regenerant solution, water softener backwash, boiler blowdown, and anodizing rinse waters. The nature of these wastewater constituent flows causes the resultant effluent pH to fluctuate markedly during the course of an operational day. As a result, Point Source 8 has a two-stage neutralization and equalization treatment facility. Wastewater from the de-ionizers and ion exchange regenerators is consolidated prior to discharge into an equalization tank (10,000 gal). Sulfuric acid anodizing solution is then pumped into the equalization tank. Anodizing rinse water and effluent from the equalization tank are discharged into a primary neutralization tank (17,900 gal) and then into a secondary neutralization tank (4,700 gal). Chemical feed for both neutralization tanks consists of sodium hydroxide and sulfuric acid. Effluent from the secondary neutralization is pumped directly into the Kokomo sanitary sewer. The water softener backwash and the boiler blowdown are not treated. The final effluent of Point Source 8 is presented in Table 72.

Point Source 9

Point Source 9 manufactures high performance nickel-base, cobalt-base, and iron-base alloys in various forms and forgings. The company also produces

TABLE 70. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 6 TO PETE'S RUN INTERCEPTOR (T-5a)

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.384	0.010	0.14	0.41	0.97	1104.90	0.45	<0.76
Day 2	0.384	≤0.004	0.022	0.19	0.16	210.40	0.21	<0.32
Day 3	0.384	≤0.008	0.055	0.27	0.27	239.52	0.51	<0.33
Mean	0.384	≤0.007	0.072	0.29	0.47	518.27	0.39	<0.47
S.D.	0.0002	0.003	0.061	0.11	00.44	508.24	0.16	0.25

TABLE 71. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 7 TO THE WASHINGTON FEEDER LINE (T-4a-2) AND THE NORTH NORTHSIDE INTERCEPTOR (T-4a) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.072	<0.001	1.31	1.12	0.039	13.53	2.43	<0.060
Day 2	0.072	<0.001	0.045	0.26	0.045	56.49	1.46	<0.060
Day 3	0.072	<0.001	0.082	0.33	0.026	43.56	0.49	<0.060
Mean	0.072	<0.001	0.48	0.57	0.037	37.86	1.46	<0.060
S.D.	0.000	0.000	0.72	0.48	0.010	22.04	0.97	0.000

TABLE 72. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 8 TO THE UNION FEEDER LINE (T-4b-1) AND THE SOUTH NORTHSIDE INTERCEPTOR (T-4b) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.264	<0.001	0.063	0.095	0.070	0.14	0.55	<0.22
Day 2	0.266	<0.001	0.031	≤0.088	0.030	2.28	0.30	<0.22
Day 3	0.288	<0.001	0.022	≤0.028	0.027	1.82	0.30	<0.23
Mean	0.273	<0.001	0.039	≤0.070	0.042	1.41	0.38	<0.23
S.D.	0.013	0.000	0.022	0.037	0.024	1.12	0.14	0.01

alloys as centrifugal sand, resinshell mold, and investment castings, as well as in the form of hard facing rods, wires, and electrodes. These materials are widely used in the aerospace, gas turbine, and nuclear industries where high temperature and corrosion resistant metals are used.

Waste treatment facilities consist of a chromium reduction and clarification system (see Figure 51). Two concrete equalization tanks (131,000 gal each) collect wastewater from various metal operations. This waste is then treated in a 400-gal acid mix tank with sulfuric acid and sulfur dioxide gas. Effluent from the mix tank is pumped into a 400-gal lime slurry reactor tank where hydrated lime is added. Discharge from the slurry tank is then emptied into a 3,000-gal flocculator. This waste is pumped into a 108,000-gal reactor-type clarifier. The sludge is thickened, using a 30,000-gal sludge thickener. Supernatant from the sludge thickener is pumped back to the equalization tank. Sludge is hauled to the company's drying beds and eventually transported to an approved state landfill. Other wastes from the facility discharged to the sanitary sewer are process water, cooling tower blowdown, boilerdown, water softener backwash, and sanitary wastes. Effluent of Point Source 9 is presented in Table 73.

The removal efficiency of the Point Source 9 treatment system was monitored for chromium, nickel, copper, and zinc. Sampling locations for raw and treated metal wastes are presented in Figure 51. Metal samples were collected every two hours for 24 hours over a consecutive three-day period. Location 1 is where raw wastewater prior to treatment was collected. Location 2 is where wastewater after treatment was collected. Removal efficiencies for chromium, nickel, copper, and zinc are presented in Table 74.

Point Source 10

Point Source 10 conducts cold rolling and metal fabrication operations of various nickel-base, cobalt-base, and iron-base alloys. Machining of the rolled and fabricated products is also carried out at this location. There are no pretreatment facilities. The final effluent from Point Source 10 is presented in Table 75.

Point Source 11

Point Source 11 provides laundry service for Kokomo residents, but no dry-cleaning operations are conducted. Approximately 9,000 pounds of laundry are serviced here a day. Other than normal laundering of domestic articles, Point Source 11 also handles uniforms from various commercial and industrial operations. No treatment facilities exist at Point Source 11. All wastewater is directly discharged to the sewer collection network. Plant effluent is presented in Table 76.

Point Source 12

Point Source 12 specializes in printing magazines (12 to 13 million each month), catalogs, brochures, books, and newspaper supplements. Water-base and solvent-base inks are both used, depending on the application. The rolls used in the printing process are both acid-etched and subsequently copper-chrome

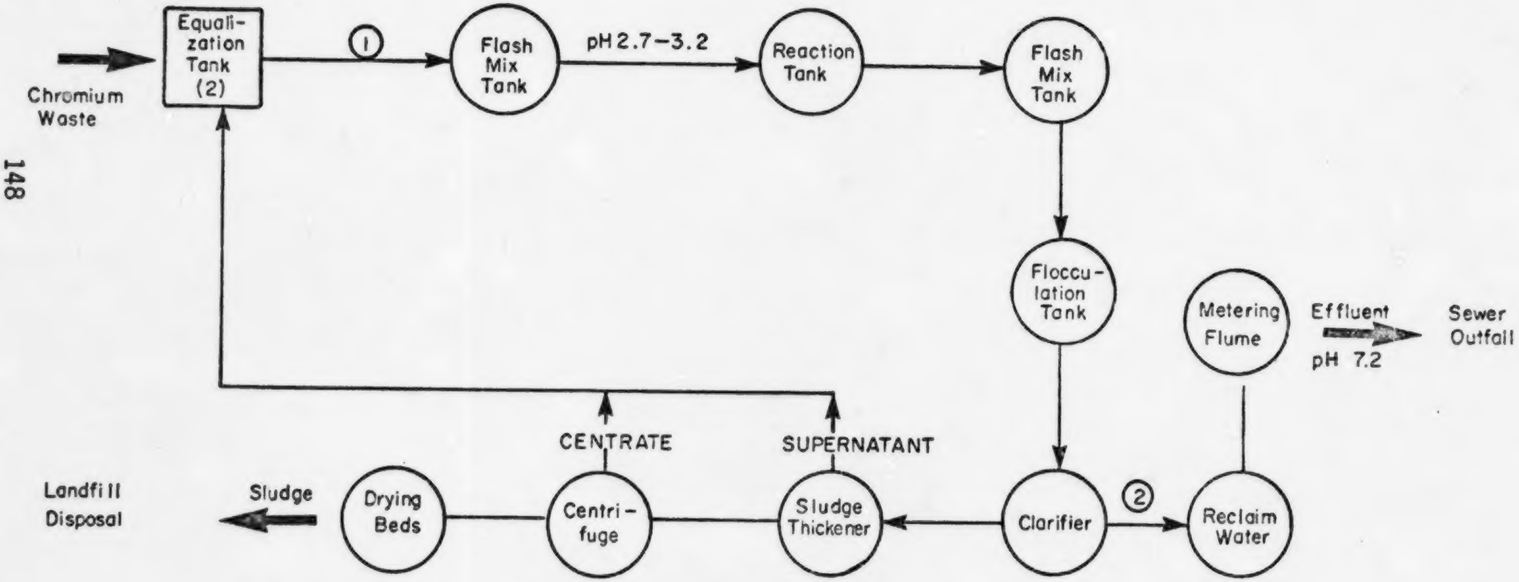
Chromium Waste
Equalization Tank (2)
①
Flash Mix Tank
pH2.7–3.2
Reaction Tank
Flash Mix Tank
Flocculation Tank
Clarifier
②
Reclaim Water
Metering Flume
Effluent
pH 7.2
Sewer Outfall
Sludge Thickener
SUPERNATANT
Centrifuge
CENTRATE
Drying Beds
Sludge
Landfill Disposal

Figure 51. Treatment system for Point Source 9.

TABLE 73. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 9 TO OLD PARK ROAD FEEDER LIINE (T-5b) AND PETE'S RUN (T-5a) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN-
Day 1	0.335	<0.003	0.39	8.25	≤0.028	0.33	0.16	<0.32
Day 2	0.335	<0.003	0.36	11.57	0.028	0.42	0.26	<0.28
Day 3	0.335	<0.004	0.63	5.34	0.028	0.42	0.28	<0.28
Mean	0.335	<0.004	0.46	8.39	≤0.028	0.39	0.23	<0.29
S.D.	0.000	0.001	0.15	3.12	0.000	0.05	0.05	0.02

TABLE 74. CONCENTRATIONS OF INFLUENT AND EFFLUENT WASTE STREAMS AND REMOVAL EFFICIENCIES FOR POINT SOURCE 9 WASTE TREATMENT SYSTEM

		Concentration (mg/l)*			
		Cr	Cu	Ni	Zn
Influent					
	Mean	169.	1.91	890.	0.49
	S.D.	121.	1.24	1450.	0.57
Effluent					
	Mean	0.27	0.008	45.8	0.047
	S.D.	0.41	0.018	65.70	0.196
Percent Removal					
		99.8	99.6	94.9	90.4

* Averaged over three-day sampling period.

TABLE 75. DAILY DISCHARGES OF METALS AND CYANIDE FROM POINT SOURCE 10 TO OLD PARK ROAD FEEDER LINE (T-5b) AND PETE'S RUN (T-5a) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	--	--	--	--	--	--	--	--
Day 2	0.058	<0.001	0.008	0.10	≤0.005	0.56	0.030	<0.048
Day 3	0.058	0.001	0.020	0.12	≤0.003	1.28	0.054	<0.048
Mean	0.058	≤0.001	0.014	0.11	≤0.004	0.92	0.042	<0.048
S.D.	0.000	0.000	0.008	0.01	0.001	0.51	0.017	0.000

TABLE 76. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 11 TO THE APPERSON FEEDER LINE (T-4a-3) AND THE NORTH NORTHSIDE INTERCEPTOR (T-4a)

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.0445	0.005	0.007	0.006	0.20	0.19	0.088	<0.041
Day 2	0.0288	0.004	0.003	0.006	0.50	0.11	0.073	<0.024
Day 3	0.0397	0.003	0.011	0.008	0.22	0.17	0.13	<0.095
Mean	0.0377	0.004	≤0.007	0.006	0.31	0.16	0.097	<0.053
S.D.	0.0080	0.001	0.004	0.002	0.17	0.04	0.031	0.037

plated and re-etched with a computer-controlled diamond stylus. The roll-plating room consists of two manual lines: 1,000 gal, 30 oz/gal copper, 10 oz/gal H_2SO_4, noncyanide copper bath; 1,000 gal, 33 oz/gal chromium bath. The secondary plating room contains a 1,500 gal copper bath and a 275 gal chromium bath.

No special treatment facilities exist. All solvents, oils, and waste inks are handled and disposed of by a company licensed for disposal of organic wastes. Other effluents (boiler blowdown, water softener regenerant) are discharged into the Kokomo sanitation network, except for the sludge (50 gal every six months) from the chrome plating tanks, which is hauled to the city's landfill area. Effluent values for Point Source 12 are presented in Table 77. Point Source 12 went out of business in the early summer of 1979.

TABLE 77. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 12 TO THE SOUTH NORTHSIDE INTERCEPTOR (T-4b) TRUNKLINE

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.144	<0.002	1.95	<0.012	0.041	0.069	2.91	<0.12
Day 2	0.204	≤0.002	7.29	<0.017	0.084	0.083	12.32	<0.17
Day 3	0.205	<0.002	5.38	<0.018	0.085	0.065	19.20	<0.18
Mean	0.184	≤0.002	4.87	<0.016	0.070	0.072	11.48	<0.16
S.D.	0.035	0.000	2.71	0.003	0.025	0.009	8.18	0.03

Street surface accumulations were sampled to estimate the input from street runoff of metals to the combined sanitary-storm collection system to the Kokomo POTW. The northern section of the city (above Wildcat Creek) was divided into a grid composed of seven segments (Figure 52), each containing three randomly selected sampling sites.

Collection of street surface accumulation was in June, 1979, and conducted according to a modified method adapted from Shaheen (1975). Each sampling site comprised an area 10 ft (3.0 m) in length parallel to the curb and 4 ft (1.2 m) in width perpendicular to the curb. One sample was taken from each site. The sampling sites selected represented residential and commercial land uses.

Both hand-sweeping and vacuum-sweeping were employed as sampling techniques to collect surface accumulations. Each collected dry sample was passed through a U.S. No. 12 sieve (1.68 mm). A 5.0 g subsample of the portion of the sample passing through the sieve was placed in a Kjelkahl flask with 20 ml redistilled nitric acid and wet digested for six hours on a heating rack. The sample was allowed to cool and then filtered through a Whatman fiber filter into a 10-ml volumetric flask. The filter was washed with 1:1 redistilled nitric acid and double distilled water and the volume adjusted to 10 ml. The samples were analyzed for zinc, copper, lead, cadmium, nickel, and chromium by AA. Each street dust sample was run in triplicate. Appropriate standards made from stock solutions and blanks were analyzed in a manner similar to field samples.

Analysis of street surface accumulations is presented in Tables 78 and 79. Table 78 contains concentrations of heavy metals in street accumulation found in the seven segments. The highest metal concentrations were found to be zinc and lead. These results were not suprising when considering that the major sources of zinc and lead are asphalt-concrete paving and leaded fuels, respectively. The type of use (i.e., residential or commercial) was also included for each sampling site. The results show no correlation between

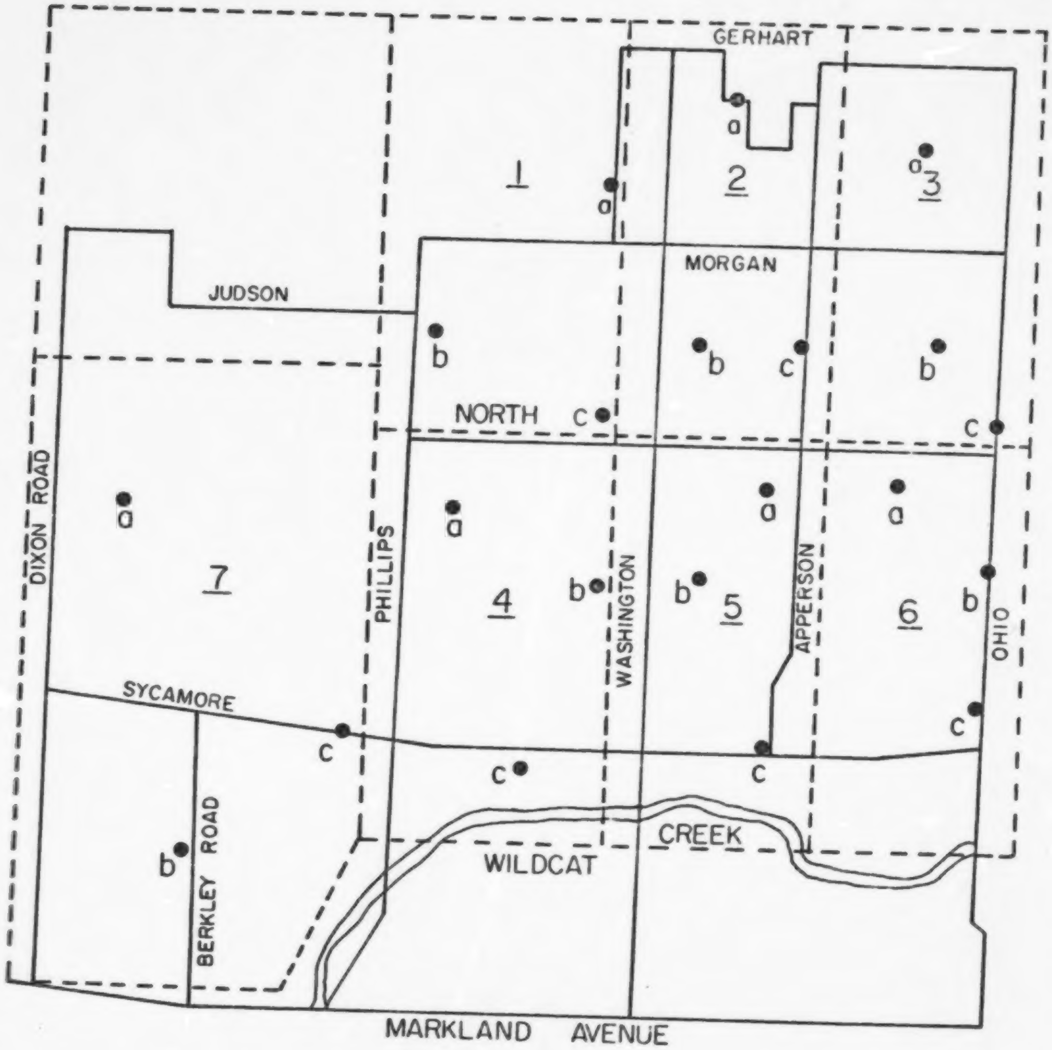
GERHART
1
2
3
MORGAN
JUDSON
NORTH
DIXON ROAD
PHILLIPS
WASHINGTON
APPERSON
OHIO
7
4
5
6
SYCAMORE
BERKLEY ROAD
WILDCAT
CREEK
MARKLAND AVENUE
a
b
c

Figure 52. Map of street surface sampling locations.

TABLE 78. CONCENTRATION OF HEAVY METALS IN KOKOMO STREET DUST (MEAN AND STANDARD DEVIATION, ug/g)

Segment	Concentration (ug/g)						
	Cd	Cr	Ni	Pb	Zn	Cu	Type
Seg 1							
a	1.49	7.41	30.45	1033.95	312.4	91.84	C*
b	0.36	0.61	40.61	214.84	100.8	10.91	R**
c	1.62	3.32	36.77	791.63	357.3	302.93	C
Mean	1.16	3.78	35.94	680.14	256.8	135.23	
S.D.	0.69	3.42	5.13	420.78	136.9	150.77	
Seg 2							
a	0.41	0.68	10.58	258.62	125.0	16.12	R
b	2.72	3.52	43.50	612.16	543.2	195.35	R
c	0.70	1.46	22.31	592.12	225.2	46.61	C/R
Mean	1.28	1.89	25.46	487.63	297.8	86.03	
S.D.	1.26	1.46	16.69	198.58	218.3	95.90	
Seg 3							
a	1.64	1.13	21.46	341.02	130.1	24.71	R
b	3.88	1.40	18.28	370.86	117.9	42.50	R
c	0.60	2.17	33.00	1089.10	263.1	53.46	R
Mean	2.04	1.57	24.25	600.33	170.4	40.22	
S.D.	1.68	0.54	7.75	423.55	80.5	14.51	
Seg 4							
a	0.97	1.05	23.52	491.12	220.5	18.93	R
b	2.90	4.07	83.89	1912.22	2969.0	231.25	C/R
c	1.93	4.26	84.68	835.13	573.5	274.59	R
Mean	1.93	3.13	64.03	1079.49	1254.3	174.92	
S.D.	0.97	1.80	35.08	741.39	1495.4	136.82	
Seg 5							
a	2.02	1.39	56.08	520.23	488.3	50.92	R
b	3.85	3.12	61.87	712.17	1051.5	178.35	C
c	2.48	4.17	54.35	1565.67	523.6	63.38	C
Mean	2.78	2.89	57.43	932.69	687.8	97.55	
S.D.	0.95	1.40	3.94	556.51	315.5	70.25	
Seg 6							
a	0.56	1.06	20.89	295.66	156.6	32.48	R
b	1.09	1.56	37.46	1400.76	305.6	60.22	R
c	2.75	3.01	65.11	1488.69	558.2	110.02	R
Mean	1.47	1.88	41.15	1061.70	340.1	67.57	
S.D.	1.14	1.01	22.34	664.87	203.0	39.29	

TABLE 78., Continued

Segment	Cd	Cr	Ni	Pb	Zn	Cu	Type
	Concentration (ug/g)						
Seg 7							
a	0.98	8.96	39.77	995.04	251.7	19.57	R
b	3.62	4.50	74.03	519.53	880.7	34.96	R
c	0.99	1.57	38.04	989.30	345.3	61.84	R
Mean	1.86	5.01	50.61	834.62	492.6	38.79	
S.D.	1.52	3.72	20.30	272.89	339.4	21.39	
Mean	1.89	2.88	42.70	810.91	499.97	91.47	
S.D.	3.22	5.85	50.22	1331.08	1601.57	240.41	

* C = Commercial

** R = Residential

TABLE 79. LOADINGS OF HEAVY METALS IN STREET DUST (LBS AND LBS/CURB-MILE)

Segment	Pounds Metal Per Segment					
	Cd	Cr	Ni	Pb	Zn	Cu
Seg 1	0.058	2.07	1.04	30.0	9.5	3.19
Seg 2	0.078	1.11	0.62	26.6	17.6	5.22
Seg 3	0.057	0.50	0.80	29.8	56.0	0.77
Seg 4	0.046	0.73	1.52	22.7	22.0	3.90
Seg 5	0.209	1.75	3.52	37.0	54.7	9.31
Seg 6	0.102	0.64	1.36	29.3	11.1	2.22
Seg 7	0.139	8.70	3.73	59.1	35.2	2.18
Total	0.689	15.52	12.59	234.5	206.1	26.79

Segment	Pounds Per Curb Mile Per Segment					
	Cd	Cr	Ni	Pb	Zn	Cu
Seg 1	0.003	0.12	0.06	1.67	0.53	0.18
Seg 2	0.003	0.06	0.03	1.10	0.73	0.22
Seg 3	0.003	0.02	0.04	1.38	2.60	0.04
Seg 4	0.001	0.02	0.05	0.71	0.69	0.12
Seg 5	0.007	0.06	0.13	1.31	1.94	0.19
Seg 6	0.005	0.03	0.06	1.37	0.52	0.10
Seg 7	0.003	0.18	0.08	1.19	0.71	0.04
Total	0.004	0.08	0.06	1.20	1.06	0.14

metal concentration and land usage. Table 79 gives loadings of heavy metals from the seven segments. The highest metal loadings were found to be zinc and lead, and again this was expected due to the sources of these two metals.

The metal loadings given are intended to serve only as a potential "reservoir" source of metal since they would not be introduced into the sewer collection system unless a substantial rainstorm or snow melt occurred. In addition, in this study the combined storm-sanitation networks did not permit an accurate determination of the quantities of metals that can wash off the street surface and be transported to the POTW since a large fraction of the surface runoff overflowed to the Kokomo Creek.

COLLECTION SYSTEM MONITORING

Figure 40 is a simplified version of the Kokomo sewer system indicating trunkline sampling points and point sources. Note that there are three primary trunklines with no known point sources discharging to them: T-1, T-2, and T-6. Note also that T-4a receives discharges from two plating shops by way of feeder line T-4a-2.

Analyses of wastewater samples obtained at 2-hour intervals in major trunk and feeder lines are given in Appendix E. Table 80 gives waste flow and metal flow summaries for the three major trunklines feeding the treatment plant which have no identified point sources discharging metals or cyanide to them (T-1, 2, 6). This study refers to these trunklines as "residential" in nature. Conversely, Table 81 summarizes metal and cyanide flows in trunklines receiving discharges from identified point sources (T-3, 4a, 4b, 5a), and they are designated as "nonresidential" in this analysis. Table 82 gives fractions of total metal input to the POTW which originate with residential and nonresidential trunklines.

Three North Northside Interceptor (Figure 40) feeder lines were sampled for a 3-day period to further elucidate the relative metal and cyanide inputs of a "residential" line (Indiana), a line receiving discharges from two electroplating shops (Washington), and a line receiving discharge from a commercial facility (Appersonway). Results of the sampling program are given in Table 83. Note that Zn flow in the Appersonway feeder is extremely high for Day 3. A check of laboratory worksheets has failed to uncover analytical errors which would explain the elevated Zn flow. Trunkline samples collected at 2-hour intervals between 6:00 p.m. and 4:00 a.m. exhibit an average Zn concentration of almost 34 mg/l. Assuming the high concentrations are real, the data strongly suggest the possibility that concentrated waste is being dumped into the Apperson Feeder.

Table 84 suggests that the Appersonway, Washington Street, and Indiana Street feeder lines account on the average for approximately 58 percent of the flow in the North Northside Interceptor, and from 51 percent to over 300 percent of the flow of metals and cyanide. The fact that feeder line and trunkline sampling was not done simultaneously evidently accounts for the >100 percent entries on Table 84. The aforementioned anomalous high Zn flow on Day 3 of the Appersonway sampling period, together with high Zn flows in the

TABLE 80. RESIDENTIAL INPUTS OF METAL AND CYANIDE TO KOKOMO POTW

Sampling Day	Trunkline Flow (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN-
Dixon Road (T-1)								
1	0.380	<0.001	0.022	0.021	0.052	0.30	0.14	0.015
2	0.478	<0.001	0.008	0.004	0.016	0.16	0.11	0.011
3	0.406	<0.001	0.014	0.029	0.023	0.16	0.14	0.015
Mean	0.421	<0.001	0.015	0.018	0.030	0.21	0.13	0.013
S.D.	0.051	<0.001	0.007	0.013	0.019	0.08	0.02	0.002
Fayble (T-2)								
1	0.273	<0.001	0.016	0.015	0.01	0.40	0.31	0.029
2	0.661	0.001	0.082	0.053	0.15	0.44	1.11	0.031
3	0.731	0.027	0.28	0.15	0.37	17.37	1.94	1.26
4	0.867	0.007	0.15	0.072	0.18	3.34	1.18	0.083
Mean	0.633	0.011	0.13	0.073	0.18	5.39	1.14	0.35
S.D.	0.255	0.011	0.11	0.057	0.15	8.11	0.67	0.61
Northwest Interceptor (T-6)								
1	0.148	0.001	0.002	0.004	0.012	0.095	0.079	0.007
2	0.086	0.003	0.001	0.002	0.005	0.041	0.006	0.006
3	0.061	<0.001	<0.001	0.002	0.003	0.018	0.018	0.003
Mean	0.098	0.002	0.001	0.003	0.007	0.051	0.034	0.005
S.D.	0.045	0.001	0.001	0.001	0.005	0.040	0.039	0.002
Sum of Daily Means	1.152	0.013	0.146	0.094	0.213	5.65	1.30	0.368

TABLE 81. NONRESIDENTIAL INPUTS OF METAL AND CYANIDE TO KOKOMO POTW

Sampling Day	Trunkline Flow (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN-
North Northside Interceptor (T-4a)								
1	3.76	5.0	33.0	5.5	0.65	57.0	3.1	1.5
2	6.18	5.2	51.0	5.5	4.6	77.0	6.9	2.9
3	3.99	2.2	30.0	3.6	0.71	45.0	2.5	1.4
Mean	4.64	4.3	40.0	5.1	2.4	62.0	4.6	2.1
S.D.	1.92	2.3	11.0	0.92	1.9	13.0	2.0	0.71
South Northside Interceptor (T-4b)								
1	0.854	0.006	0.416	0.058	0.120	2.27	1.61	0.089
2	0.903	0.001	0.165	0.087	0.069	11.90	1.02	0.013
3	0.829	0.011	0.14	0.045	0.086	2.37	0.61	0.024
Mean	0.862	0.006	0.240	0.063	0.092	4.52	1.08	0.042
S.D.	0.053	0.003	0.125	0.018	0.021	5.51	0.410	0.034
Pete's Run Interceptor (T-5a)								
1	1.53	0.067	0.24	0.85	0.54	6.86	2.98	0.4
2	0.961	0.044	0.23	0.45	0.56	5.4	1.7	0.1
3	1.33	0.018	0.18	0.95	0.80	2.6	2.9	0.07
Mean	1.27	0.043	0.22	0.75	0.63	4.95	2.5	0.19
S.D.	0.23	0.02	0.03	0.22	0.12	1.8	0.59	0.15
New Pete's Run Interceptor (T-3)								
1	3.057	3.62	0.22	3.99	0.33	14.47	15.82	9.07
2	2.628	3.12	0.99	3.07	0.30	8.96	9.11	5.09
3	2.286	2.62	2.52	2.52	0.26	6.38	9.06	3.35
Mean	2.657	3.12	1.24	3.56	0.30	9.94	11.33	5.84
S.D.	0.386	0.50	1.17	0.46	0.04	4.13	3.89	2.93
Sum of Daily Means	9.43	7.47	41.7	9.47	3.4	81.4	19.5	8.17

TABLE 82. PERCENT INPUT OF METALS AND CYANIDE TO KOKOMO POTW FROM RESIDENTIAL AND NONRESIDENTIAL TRUNKLINES

Source	Percent Input to POTW						
	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Residential	0.2	0.3	1.0	5.9	6.5	6.2	4.3
Nonresidential	99.8	99.7	99.0	94.1	93.5	93.8	95.7

TABLE 83. DAILY AVERAGE METAL AND CYANIDE FLOWS IN THREE NORTH NORTHSIDE INTERCEPTOR FEEDER LINES

Sampling Day	Trunkline Flow (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Appersonway Feeder Line								
1	0.864	0.018	0.042	0.78	0.097	2.45	0.27	0.043
2	0.852	0.036	0.70	0.50	0.095	2.67	0.42	0.034
3	0.803	0.029	0.15	0.65	0.083	110.09	0.23	<0.001
Mean	0.840	0.028	0.30	0.64	0.092	38.40	0.31	0.025
S.D.	0.032	0.009	0.35	0.14	0.008	62.08	0.10	0.023
Washington Street Feeder								
1	1.553	2.25	35.89	1.83	0.21	87.91	3.23	2.26
2	1.575	1.54	38.85	2.61	0.19	30.74	2.64	1.08
3	1.648	2.68	28.22	4.32	0.33	38.66	13.05	16.13
Mean	1.592	2.16	34.32	2.92	0.24	52.44	6.31	6.49
S.D.	0.050	0.58	5.49	1.27	0.08	30.97	5.85	8.37
Indiana Street Feeder Line								
1	0.208	0.006	0.091	0.007	0.005	5.37	0.070	<0.001
2	0.220	0.001	0.005	0.007	0.025	0.40	0.081	0.010
3	0.314	0.001	0.13	0.088	0.045	3.38	18.53	0.010
Mean	0.247	0.008	0.075	0.034	0.025	3.05	6.23	0.006
S.D.	0.058	0.003	0.064	0.047	0.020	2.50	10.65	0.006
Sum of Daily Means	2.68	2.19	34.7	3.59	0.357	93.9	12.9	6.52

TABLE 84. FRACTIONS OF WASTEWATER, METALS AND CYANIDE FLOWS IN NORTH NORTHSIDE INTERCEPTOR ATTRIBUTABLE TO APPERSONWAY, WASHINGTON STREET, AND INDIANA STREET FEEDERS*

Total Flow (mgd)	Pounds Per Day						
	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
0.58	0.51	0.87	0.70	0.15	1.51	2.8	3.1

* Estimates based on nonsimultaneous sampling of trunk and feeder lines.

Washington feeder line which serves two electroplating shops, constitute 92 percent of the combined feeder line Zn flow to the North Northside Interceptor. It can be seen from Tables 68 and 69 that the sum of the Zn discharges from the two electroplating facilities is 221.3 lbs/day for the respective sampling periods. This is in close agreement with the Zn flow found in the Washington feeder line during the sampling period.

A mechanism other than comparison of overall mean flow rates can be used to estimate whether or not measured sources of metals and cyanide account for flows observed in a receiving trunkline. This method involves constructing all possible combinations of daily average flows from measured sources for the purpose of determining likely pollutant flow limits in a receiving trunkline. For example, assume there are three sources feeding a trunkline whose discharges have been measured (nonsimultaneously) for three days each. There are then nine possible combinations of daily averages that may be constructed. If it is assumed that discharges from the three sources are not correlated (i.e. there are no process variables or maintenance practices keyed to particular days of the week, etc.), the upper and lower flow limits resulting from the nine possible daily average discharge combinations may be interpreted as measures of the flow limits likely to be seen in a receiving trunkline. This approach is referred to here as the method of "random superposition." Its application to the three feeder lines to the North Northside Interceptor is given in Table 85. Note that while the mean Ni flow from the three feeders represents only 70 percent of the mean interceptor flow, the random superposition upper limit feeder flow is 94 percent of the interceptor upper limit. This suggests that the three feeders may account for enough of the interceptor Ni flow that supplementary sampling would not be required to indentify Ni point sources upstream from the feeder-interceptor junctions.

A comparison of Tables 68, 69, 71, and 83 indicates that the sum of the mean daily Cu and CN discharges from the three point sources tested accounts for only 40 and 25 percent, respectively, of the Cu and CN flows in the Washington Street feeder line. This suggests the possibility of unidentified sources of Cu and CN. However, Table 83 indicates that for two of the three sampling days, the mean Cu and CN flows are, respectively, 2.9 and 1.7

TABLE 85. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED APPERSONWAY, WASHINGTON STREET, AND INDIANA STREET FEEDERS

Parameter	Flow limits (lbs/day)			
	Combined Feeders		North Northside Int.	
	Upper	Lower	Upper	Lower
Cd	2.72	1.56	5.2	2.2
Cr	39.7	28.3	51.0	30.0
Ni	5.19	2.34	5.5	3.6
Pb	0.47	0.28	4.6	0.65
Zn	203.0	33.6	77.0	45.0
Cu	32.0	2.94	6.9	2.5
CN^-	16.2	1.08	2.9	1.4

pounds/day. This compares in magnitude to the sum of the Cu and CN discharges from Point Sources 4 and 5. The bulk of the mean Cu and CN flows in the Washington feeder derive from high flows on Day 3. Since the other metals do not exhibit marked relative increases for Day 3, this suggests the discarding of concentrated Cu-CN plating waste, probably from Point Source 5, was an alternative explanation to unidentified sources discharging to the Washington feeder.

Point Sources 1, 2, and 3 discharge to the New Pete's Run trunkline (T-3). Table 86 gives the fractions of total flow, metals, and cyanide in New Pete's Run represented by the sum of the mean daily discharges from these three point sources, as given in Tables 65, 66, and 67.

It suggests the possibility of other (unidentified) point sources discharging Cd, Cr, Ni, and CN to the trunkline. The high mean Cr flow in New Pete's Run is primarily the result of an extremely high flow on one of the three days the trunkline was sampled. An alternative hypothesis (to an unidentified point source) could be a breakdown of the Point Source 3 Cr treatment system during trunkline sampling. Table 87 presents a comparison of random superposition pollutant flow limits for the three point sources with maximum and minimum daily mean flows in New Pete's Run. This comparison suggests the same conclusion stated above, that is, Cd, Cr, Ni, and CN are not well accounted for by discharges from Point Sources 1, 2, and 3.

Tables 88, 89, and 90 give point source random superposition flow limit comparisons for the Washington Street Feeder, Pete's Run Interceptor, and South Northside Interceptor, respectively. The Washington Street Feeder receives discharges from two electroplating shops (Point Sources 4 and 5) and a Zn galvanized fence production facility. Once again, the superimposed maximum and minimum point source Cd discharge rates are substantially lower than the observed feeder line flow limits. The relatively high Cu and CN feeder line flows may be due to a batch dump of a Cu-CN plating solution

TABLE 86. FRACTIONS OF WASTEWATER, METALS, AND CYANIDE FLOWS IN NEW PETE'S RUN TRUNKLINE ATTRIBUTABLE TO POINT SOURCES 1, 2, AND 3

Total Flow (mgd)	Pounds Per Day						
	Cd	Cr	Ni	Pb	Zn	Cu	CN-
0.96	0.26	0.18	0.30	0.83	3.4	0.76	0.51

TABLE 87. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 1, 2, AND 3 EFFLUENT

	Flow Limits (lbs/day)			
	Combined Sources		New Pete's Run Int.	
Parameter	Upper	Lower	Upper	Lower
Cd	0.95	0.70	3.62	2.62
Cr	0.31	0.17	2.52	0.22
Ni	1.48	0.78	3.99	2.52
Pb	0.42	0.16	0.33	0.26
Zn	48.3	19.6	14.5	6.38
Cu	12.2	5.81	15.8	9.06
CN-	2.95	0.98	9.07	3.35

TABLE 88. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 4, 5, AND 7 EFFLUENT

	Flow Limits (lbs/day)			
	Combined Sources		Washington Feeder	
Parameter	Upper	Lower	Upper	Lower
Cd	0.94	0.36	2.68	1.54
Cr	143.0	45.4	38.9	28.2
Ni	7.36	3.72	4.32	1.83
Pb	0.61	0.12	0.33	0.19
Zn	92.3	15.8	87.9	30.7
Cu	4.23	1.25	13.1	2.64
CN-	.038	.030	16.3	1.08

TABLE 89. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 9 AND 10 EFFLUENT

Parameter	Flow Limits (lbs/day)			
	Combined Sources		Pete's Run Int.	
	Upper	Lower	Upper	Lower
Cd	0.00025	0.002	0.0067	0.018
Cr	0.65	0.37	0.24	0.18
Ni	11.7	5.44	0.95	0.45
Pb	0.033	0.031	0.80	0.54
Zn	1.7	0.89	6.86	2.6
Cu	0.33	0.19	2.98	1.7
CN-	0.19	0.16	0.40	0.072

TABLE 90. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 8 AND 12 EFFLUENT

Parameter	Flow Limits (lbs/day)			
	Combined Sources		South Northside Int.	
	Upper	Lower	Upper	Lower
Cd	0.0015	0.0015	0.011	0.001
Cr	7.35	1.98	0.416	0.14
Ni	0.11	0.22	0.087	0.045
Pb	0.16	0.068	0.12	0.069
Zn	2.36	0.21	11.9	2.27
Cu	19.8	3.2	1.61	0.61
CN-	0.21	0.17	0.089	0.013

during Day 3 (Table 83). The Pete's Run point source-trunkline flow limit comparison indicates that interceptor Zn and Cu flows are not accounted for by Point Sources 9 and 10 combined discharges. The high Ni discharge is from Point Source 9, evidently related to the production of Ni-based alloys during the sampling period. Finally, the South Northside Interceptor-point source flow comparison indicates that all interceptor metal flows, except Zn, are accounted for by Point Sources 8 and 12. Inspection of Table 72 indicates a significant and highly variable Zn discharge from Point Source 8. This suggests that the high interceptor Zn flows may result from a process solution batch dump or markedly increased production activity at Point Source 8 during Day 2 of interceptor sampling (Table 66).

RESULTS AND DISCUSSION

The primary focus of this work was to determine flow characteristics of heavy metals and cyanide in the Kokomo waste treatment system. Major elements of the flow picture include discharges from point sources served by the collection system, movement within the collection system that reflects the existence of both point and area sources, and fates of metals entering the system. Emphasis was placed on concentrations in sludge and resulting limitations on sludge disposal options. Table 91 compares metal concentrations measured in Kokomo sludge cake and estimates concentrations related to trunkline flows and point source discharges.

Cadmimum

Point source discharges of Cd account for little more than half of that found in sludge cake and less than 20 percent of combined trunkline flows. Inspection of Tables 65 through 77 indicates that only Point Sources 2, 3, and 5 show significant Cd discharges. Tables 80 and 81 indicate that virtually all Cd trunkline flow is observed in the North Northside and New Pete's Run Interceptors. These trunklines serve, respectively, Point Source 5 (North Northside) and Point Sources 2 and 3 (New Pete's Run).

This strongly suggests that the significant Cd point sources have been identified, and that trunkline sampling was carried out at a time when Point Sources 2, 3, and 5 were discharging higher than average amounts of Cd, while point source testing was conducted during periods of relatively low discharge. In support of this contention, the Cd plating line at Point Source 5 operates only periodically and at differing levels of activity (area plated/hour). Cadmium flow in the Washington Street Feeder which receives Point Source 5 waste (Table 83) averages 2.16 lbs for three sampling days. This is very close to the 2.2 lbs flow seen in the North Northside Interceptor on sampling Day 3.

It is recommended that further sampling be conducted at Point Source 2, 3, and 5 to characterize their discharges and identify other point sources of Cd over a longer period than the three days of this study. If this fails to account for Cd observed in the POTW sludge, it is recommended that trunkline sampling be conducted in the North Northside Interceptor upstream from, and as close to, the Washington Street Feeder junction as reasonable access permits.

Chromium

Unlike Cd, point source discharges more than account for Cr flows observed in major trunklines, and both result in substantially larger projected Cr concentrations in POTW sludge than have been measured. Thus no supplementary source or trunkline monitoring are necessary for source identification purposes. Approximately 95 percent of the Cr entering the POTW flows from the North Northside Interceptor (Table 81). Table 83 indicates that of the three feeder lines discharging to this interceptor, the Washington Street line accounts for 99 percent, i.e., 34.3 lbs/day. This in turn represents 82 percent of the average flow detected during the interceptor sampling period.

TABLE 91. COMPARISON OF METAL CONCENTRATIONS IN SLUDGE CAKE

Basis of Projection	Sludge Metal Concentration (mg/kg dry wt.)						
	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Sludge cake analysis	377	1,060	533	---	13,600	1,790	---
Trunkline flow*	1,100	7,270	550	600	14,100	3,230	1,580
Point source discharge*	202	16,400	830	280	100,000	3,760	1,380

* Based on per capita sludge generation rate of 0.12 lbs/day (dry wt.), and POTW metal removal rates determined in, "A Mass Balance of Several Heavy Metals Around an Operational Activated Sludge-Gravity Filter Municipal Sewage Treatment Plant," by Bert Michalczyk.

Point Sources 4 and 5, two electroplating facilities, are served by the Washington Street feeder. The sum of the average Cr discharges observed during their respective monitoring periods is approximately 92 lbs/day, with 83.2 lbs/day originating with Point Source 5. Installation of a Cr reduction unit, followed by pH adjust and clarifier steps at Point Source 5, would achieve the greatest reduction in Cr discharges to the POTW. A modest 90 percent treatment efficiency at Point Source 5 would reduce the POTW sludge Cr concentration by an estimated 92 percent to a level of approximately 90 mg/kg.

Nickel

The POTW sludge-cake analysis and projected sludge Ni concentration based on trunkline monitoring are virtually the same. The sum of the point source discharges gives a projected source-related sludge Ni concentration more than 50 percent higher. Thus there is no indication that further trunkline or source sampling are required to identify sources of Ni to the system, other than those sampled in this work.

Of the 9.6 lbs/day Ni flow observed in the total of the six major trunkline average flows, 5.1 lbs were seen in the North Northside Interceptor and 3.6 lbs in the New Pete's Run Interceptor (Table 81). Table 83 shows a highly variable Ni flow in the North Northside Washington Street feeder which averages 2.92 lbs/day. The Washington Street feeder receives discharges from Point Sources 4 and 5. The latter discharged an average of 4.8 lbs/day of Ni during the three-day source monitoring period. This compared closely with, and would appear to account for, the 5.1 lbs/day average flow seen in the North Northside Interceptor.

New Pete's Run Interceptor receives discharges from Point Sources 1, 2, and 3. Inspection of Tables 65, 66, and 67 indicates that while Point Sources 1 and 3 are significant dischargers of Ni, the sum of their daily average discharges is less than 1 lb/day, which represents less than 30 percent of the average daily flow observed in New Pete's Run. Of the other major trunklines, only Pete's Run, which serves Point Sources 9 and 10 upstream from the trunkline sampling location, exhibits a significant Ni flow. Tables 73 and 75 indicate that Point Source 9 discharged a daily average of 8.4 lbs/day during a three-day monitoring period, i.e., almost 55 percent of the total Ni discharges observed during the entire point source monitoring program. A summary of Point Source 9 waste treatment system performance in Table 74 suggests that the relatively high Ni discharge is a consequence of an extremely high Ni concentration in the raw (untreated) waste, i.e., in the range of 900 to 1,500 mg/l.

Based on this information, it would appear that Point Sources 1, 3, 5, and 9 are the primary point source dischargers of Ni to the collection system. Although the point source and trunkline monitoring for the Pete's Run and New Pete's Run Interceptors did not exhibit good correlation between source discharges and trunkline flows of Ni, further monitoring to identify other point sources does not appear necessary.

A strategy to reduce Ni discharges to the POTW would include installation of a pH adjust step and a clarifier at Point Source 5, and a change in the Point Source 9 waste treatment system to optimize Ni removal from the Ni-rich raw waste. This could involve either a segregated Ni treatment system, or an upward shift of clarifier pH toward the Ni minimum solubility value of approximately 10.

Lead

The metals balance conducted on the Kokomo POTW was not completed for Pb due to analytical difficulties encountered in the project laboratory. Projected Pb concentrations in sludge cake resulting from trunkline flows and point source discharges are 600 mg/kg and 280 mg/kg, respectively (Table 91). Table 81 indicates that the North Northside Interceptor accounts for 66 percent of the trunkline flow, Pete's Run Interceptor, 17 percent, and the New Pete's Run Interceptor, 8 percent. Table 83 exhibits 0.36 lbs/day total Pb flow for the three major North Northside Interceptor feeders, i.e. substantially below the interceptor Pb flow (Table 84). A survey of Tables 65 to 77 indicates significant discharges from Point Sources 3, 5, 6, and 12. All but Point Source 12 discharge to one of the three trunklines for which significant Pb flows were detected.

The probable explanation for the twofold difference between trunkline Pb flows and source discharge rates is metal entering the combined storm-sanitary collection system during coincident trunkline sampling and precipitation events, or pavement runoff which is resuspended during high-flow trunkline sampling periods immediately after precipitation events. Table 79 indicates an average Pb concentration of 810 mg/kg in Kokomo pavement dust. The bulk of this is presumed to originate with automotive exhaust gases from vehicles burning leaded gasoline. Table 79 exhibits total Pb loadings in pavement dust per curb mile, with an average of 1.2 lbs of Pb per curb mile. Since the combined storm-sanitary system serves approximately 100 curb miles, the runoff of even a small fraction of street dust in a major precipitation event would more than account for the trunkline flow-point source discharge discrepancy.

With this in mind, no supplementary trunkline or point source sampling is required to account for Pb inputs to the system. As vehicles burning leaded fuel are retired from service, POTW Pb input will presumably decrease.

Zinc

Close agreement between the measured sludge-cake Zn concentration and the projected concentration based on trunkline flow measurements is shown in Table 91. Note that the sum of the average daily Zn discharges from the twelve point sources is a factor of seven higher, so there is evidently no further sampling required to identify sources of Zn to the Kokomo treatment system. A survey of Tables 65 to 77 indicates that Point Sources 3, 4, 6, and 7 are the major Zn dischargers. Table 70 exhibits an extremely high Zn discharge for Point Source 6 the first sampling day. In particular, this single-day Zn discharge constitutes 60 percent of the sum of the daily average discharges for all twelve point sources monitored. Inasmuch as Point Source 6 is a steel remelt, wire-fence-fabricating facility, the likely explanations are the processing of scrap rich in Zn galvanized material, or a flotation problem in the plant clarifier (Figure 50), or both.

Significant reductions in Zn discharges to the Kokomo treatment system could be effected by running a series of jar tests (metal solubility vs. pH) on Point Source 6 clarifier solution to determine an optimum pH for Zn precipitation. This same protocol could be used to reduce Zn discharges from Point Sources 3 and 4, though changes in clarifier pH in these cases would represent compromises between Zn and Cu, and Zn and Cr, respectively. Finally, Point Source 7 (a galvanizing operation) should be required to install a pH adjust and clarifier system to remove Zn from process water discharged to the municipal system.

Copper

The sum of the point source discharges of Cu is in close agreement with the cumulative trunkline flow, and both result in a projected Cu concentration in sludge cake which substantially exceeds measured values (Table 91). The primary dischargers of Cu to the Kokomo treatment system are Point Sources 2, 3, 7, and 12. Point Sources 2 and 3 are electronics/semiconductor and circuit board-producing facilities with waste treatment systems in operation. They account for 35 percent of the Cu discharged to the municipal system. Since Point Source 2 discharges no other metals at rates comparable to Cu, clarifier pH at this facility could presumably be optimized for Cu precipitation to effect a discharge reduction. Optimizing the Point Source 3 treatment system pH for Cu removal must be undertaken with some care to insure that removal of other metals, notably Cd and Zn, is not unduly compromised. Since neither Point Source 7 (Zn galvanizing facility) nor Point Source 12 (printing plant) has treatment systems, installation of properly sized pH adjust-clarifier systems at these sites would substantially reduce their Cu discharges.

A comparison of trunkline Cu flows (Tables 80 and 81) with point source discharges (Tables 65 to 77) reveals a lack of correlation between them. In particular, the Fayble trunkline exhibits a significant Cu flow, although there are no known point sources discharging to it. Further, Cu flow in

Pete's Run Interceptor averaged 2.5 lbs/day, while Point Sources 9 and 10 which discharge to it account for only 0.27 lbs/day. Thus further monitoring of Point Sources 9 and 10 discharges is in order to determine if they can account for Cu flows in the Pete's Run Interceptor. If not, then supplementary trunkline sampling would be called for above the Old Park Road feeder function. Further, the Fayble trunkline contributes a projected 210 mg/kg Cu to the POTW sludge cake concentration. If the Cu discharge reduction measures outlined previously do not reduce Cu concentrations sufficiently for disposal purposes, it might be necessary to embark on a trunkline sampling program in order to locate the source(s) responsible for the observed metal flow.

Cyanide

No cyanide analyses were performed on Kokomo sludge cake. As indicated in Table 91, the projected sludge CN concentrations based on trunkline and source monitoring results are 1,580 and 1380 mg/kg, respectively. Since the sum of the point source CN discharges is within 12 percent of measured trunkline flows, no further sampling is deemed necessary to identify sources. This conclusion is also based on the fact that, except for sampling Day 3 on the Fayble trunkline, the only substantial CN flows were detected in the North Northside and New Pete's Run Interceptors (Tables 80 and 81).

A survey of Tables 65 to 77 shows that both of these trunklines receive substantial discharges from monitored point sources, i.e., Point Sources 5 to North Northside and Point Source 3 to New Pete's Run. Note in Table 83 the high CN flow in the Washington Street feeder on sampling Day 3. This suggests that Point Source 5 was dumping a cyanide plating solution at that time. This contributed 5.4 lbs/day to the daily average CN flow in the Washington Street feeder, and represents 66 percent of the total CN flow detected in the six major trunklines. Substantial reductions can be made in CN discharges to the municipal system through installation of a CN destruct system at Point Source 5 and improvement in the efficiency of the CN destruct unit at Point Source 3.

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APPENDIX A

MODIFICATIONS OF EPA TOTAL METALS METHODOLOGY

The EPA method for total metals was modified slightly in three ways to facilitate rapid analysis of samples. One change was the addition of 5 ml rather than 3 ml of HNO_3 to the aliquot being evaporated. It was found that this quantity of acid greatly enhances dissolution of any oil or grease which might be present and which "burns" the glass if not removed or dissolved. Second, the digested sample was not filtered to remove silicates prior to analysis. This was mainly a time-saving step but was justified on the basis that the samples were not analyzed immediately, thus allowing insoluble material to settle. If care is taken to aspirate only from the top portion of the sample, clogging of the atomizer is prevented.

A 90-minute digestion time for both the nitric and hydrochloric acids was chosen in deference to the EPA method of digesting to a light-colored residue in order to speed up analysis. The justification is based on an investigation carried out to determine the effect of both HNO_3 and HCl digestion times. In summary, the procedure:

(1) digests 10 samples for a fixed length of time using nitric acid (90 minutes) followed by varying periods of hydrochloric acid digestion (0, 30, 60, 90, 120, 180, 240 minutes).

(2) digests 10 samples for varying lengths of time using nitric acid (0, 30, 60, 90, 120, 180, 240 minutes) followed by a fixed (90-minute) hydrochloric acid digestion.

The results presented in Table A-1 and Figures A-1 and A-2 indicate that the length of time of the HNO_3 digestion has a greater effect than does the length of time of the HCl digestion. At a 90-minute HNO_3 digestion time, the metal level reported was always near the average as opposed to the metal level reported at other times. And since there was no discernible trend in the data, a 90-minute digestion time was chosen for HNO_3. For convenience, a 90-minute period was also chosen for HCl digestion.

TABLE A-1. RESULTS OF INVESTIGATIONS OF HNO$_3$ AND HCl DIGESTION TIME VARIATIONS

Length of Time of HCl Digestion[1] (min.)	Metal Conc. (mg/l)				
	Cd	Cr	Cu	Ni	Zn
0	0.220	0.969	0.614	1.51	7.34
30	0.249	1.01	0.702	1.44	7.28
60	0.219	1.07	0.612	1.58	7.63
90	—	—	—	—	—
120	0.240	1.00	0.652	1.60	7.24
180	0.237	0.968	0.701	1.49	7.44
240	0.200	0.905	0.606	1.38	6.70

[1] 90 min. HNO$_3$ digestion time.

Length of Time of HNO$_3$ Digestion[2] (min.)	Metal Conc. (mg/l)				
	Cd	Cr	Cu	Ni	Zn
0	0.273	1.07	0.977	1.92	10.4
30	0.338	1.23	1.03	1.58	11.4
60	0.314	1.09	0.781	2.08	11.1
90	0.316	1.07	1.03	2.19	11.6
120	0.264	0.980	1.04	2.09	10.1
180	0.320	1.08	1.24	2.17	15.6
240	0.328	0.943	1.12	1.82	10.4

[2] 90 min. HCl digestion time.

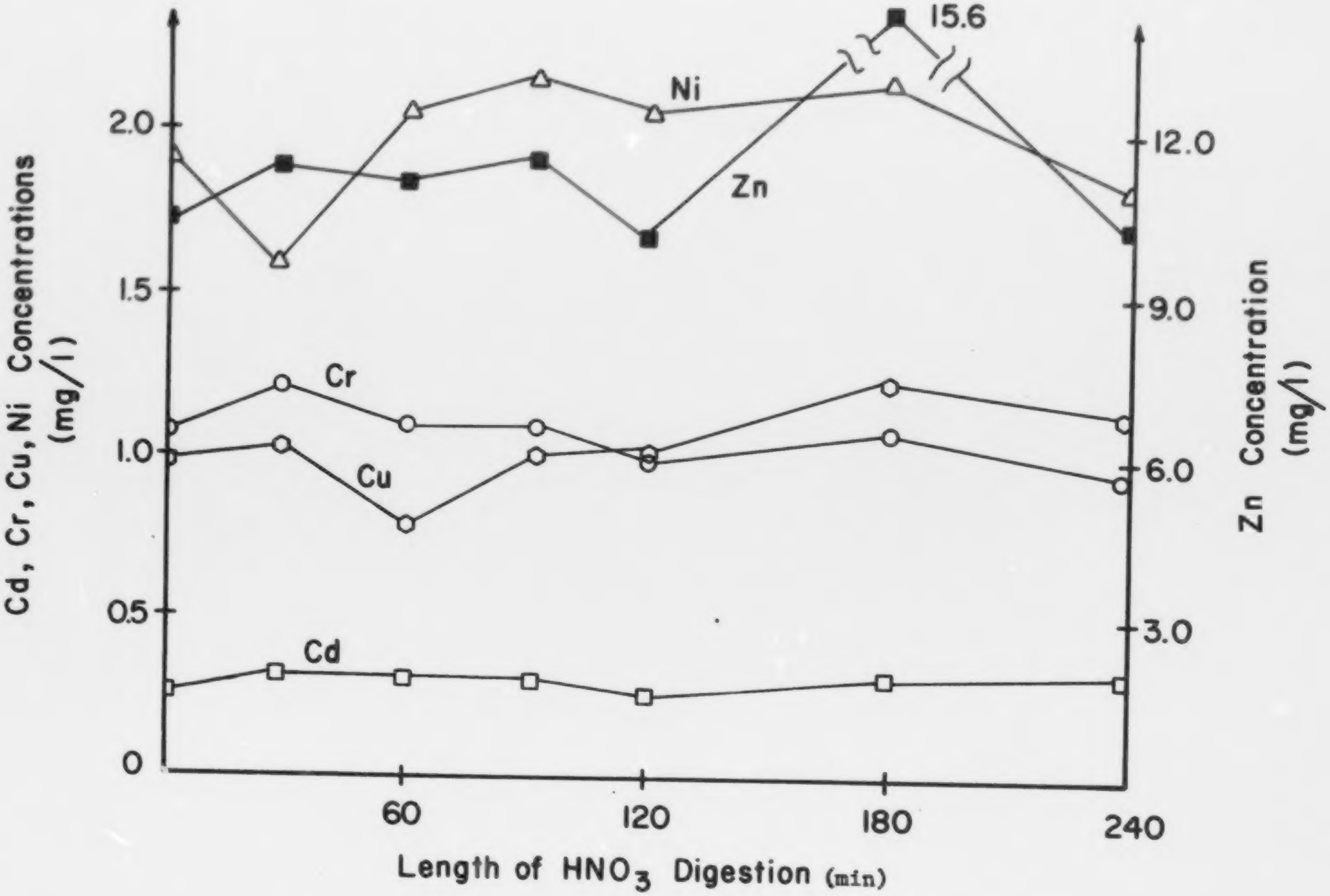

Figure A-1. Effect of various HNO_3 digestion times on metal concentrations.

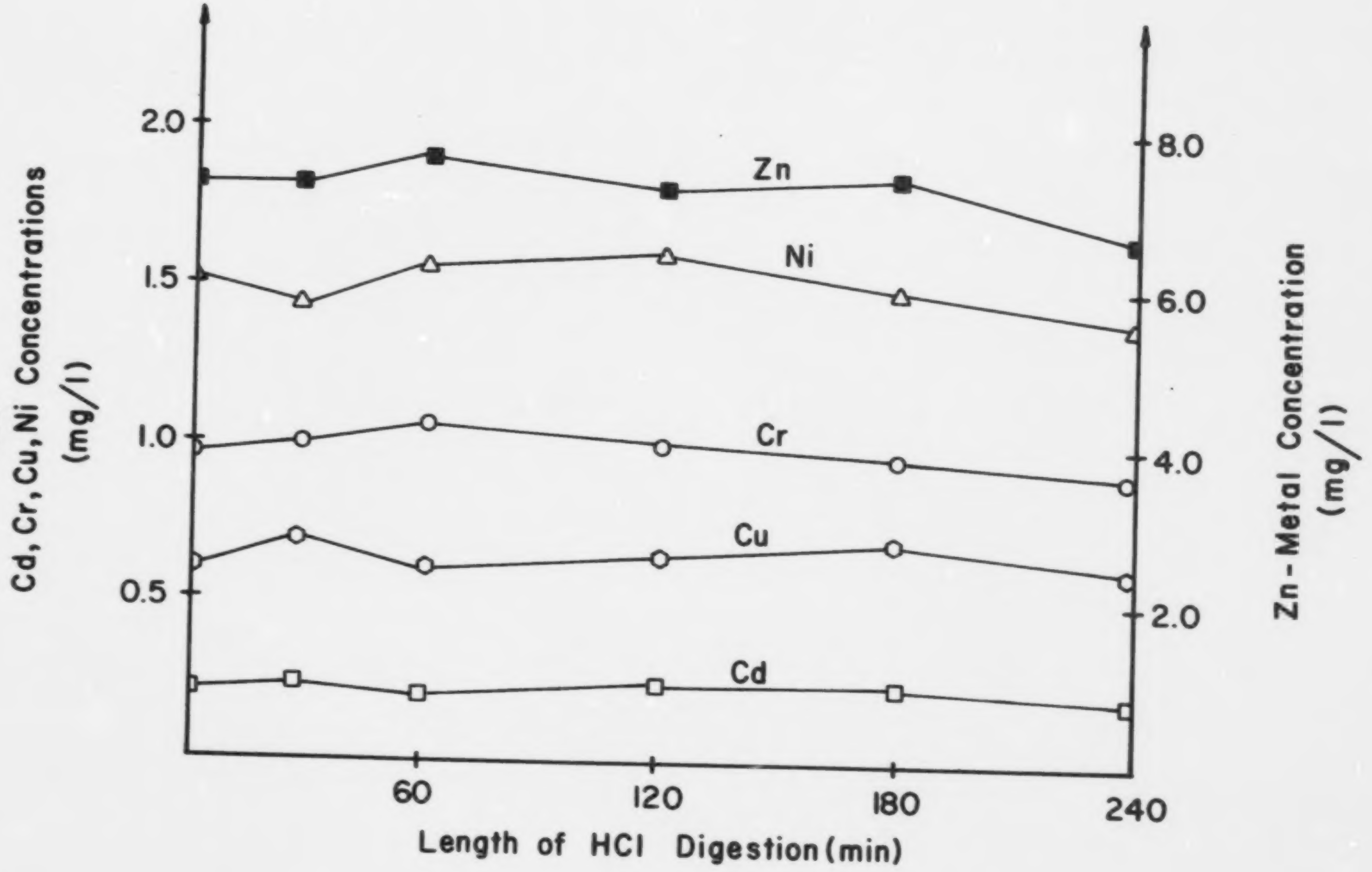

Figure A-2. Effect of various HCl digestion times on metal concentrations.

APPENDIX B

OPERATIONAL SETTINGS FOR PERKIN-ELMER ATOMIC ABSORPTION SPECTROPHOTOMETERS

During this study, two atomic absorption spectrophotometers were used: a Perkin-Elmer 306 and a Perkin-Elmer 603. Although the machines were different in appearance, fundamental controls were the same, thus allowing only one explanation of the setting used.

A detailed discussion of atomic absorption spectrophotometry is impossible in this report, however, the fundamental control variables need explanation. These can alter the results obtained mainly through spectral and other interferences. These variables are wave length, slit width, fuel-air ratio, burner height and orientation, and energy output of the intrument. The proper setting of each of these is listed in Table B-1 for each element.

In brief, each element absorbs light of a characteristic wave length and the machine must be tuned to that particular wave length, even though a specific element lamp is used. That lamp, while emitting the desired wave length, also emits others which are unnecessary and which can interfere with analyses. The slit width controls the width of the spectral band about the desired wave length. A narrower band is necessary for an element with closely spaced, intense spectral lines. The fuel-air ratio affects the temperature of the flame, and hence excitation of the element in question. For example, an easily excited element like chromium must be done with a cooler flame to avoid interferences. The burner orientation should be arranged so that the light beam passes over the entire length of the burner and the height should maximize absorbance. The energy output is a measure of the energy added through the photomulitiplier tube that serves as an amplifier for the detection device. This should be set in such a way that the reading never goes off-scale.

TABLE B-1. OPERATIONAL DATA OF THE ATOMIC ABSORPTION SPECTROPHOTOMETER.

Element	Wavelength	Slit Width	Flame[1]
Cd	228.8 nm	4	oxidizing
Cr	357.9 nm	4	reducing
Cu	324.7 nm	4	oxidizing
Ni	232.0 nm	3	oxidizing
Zn	213.9 nm	4	oxidizing
Fe	372.0 nm	3	oxidizing
Pb	283.3 nm	4	oxidizing

[1] oxidizing - fuel lean

reducing - fuel rich

In all cases the fuel is acetylene and the oxidant is air.

APPENDIX C

CALCULATIONS TO DETERMINE FLOW RATES OF THREE SELECT STREAMS IN THE KOKOMO, INDIANA, TREATMENT PLANT

RAS AND WAS FLOW MEASUREMENT CONCEPTS

The flow rates of waste-activated sludge and return-activated sludge were determined using a series of pump characteristic curves supplied by Allis-Chalmers, the manufacturer of the six pumps used. These pumps were powered by variable frequency drives (VFD) which vary the impeller speed to obtain various flow rates. After about Day 10, however, the pumps were only run at 100 percent capacity because of the treatment plant management's feeling that using the VFD caused excessive operational and maintenance problems. Meters were only available indicating the percentage of the maximum impeller speed at which the pumps were operating. Only after project completion were the flow meters made operational. This posed some problem in compositing samples during the first ten-day period; to do so entailed assuming a linear proportional decrease of flow rate with percentage of maximum. As will be seen later, this was a valid approximation.

This method basically involved using the curves supplied by Allis-Chalmers, specific for these pumps and which showed the total head as a function of flow rate with impeller speed as a parameter. This graph is shown in Figure C-1. The static head was calculated from elevations obtained from construction plans for the plant. When the flow meter was finally put in operation, one operating point was obtained, that is, at 4,200 gpm the total head was 32.9 ft, as determined from Figure C-1. The dynamic head was then calculated as the difference between the total and static heads. This head is proportional to the flow rate squared, allowing calculation of the proportionality constant. Knowing this, the head could be calculated for any flow rate and operating lines plotted, as in Figure C-1. To then determine the flow rate associated with a given pump setting, it is necessary to calculate the percent of the rated impeller speed for each of the parametric curves. The intersection of these curves and the operating line shows the total head and the desired flow rate for that speed. The calculations necessary for this are presented below. Figure C-2 is a plot of flow rate versus pump speed for the RAS and WAS pumps. Note the agreement between these and the assumed linear curve used for compositing the samples at the higher values used.

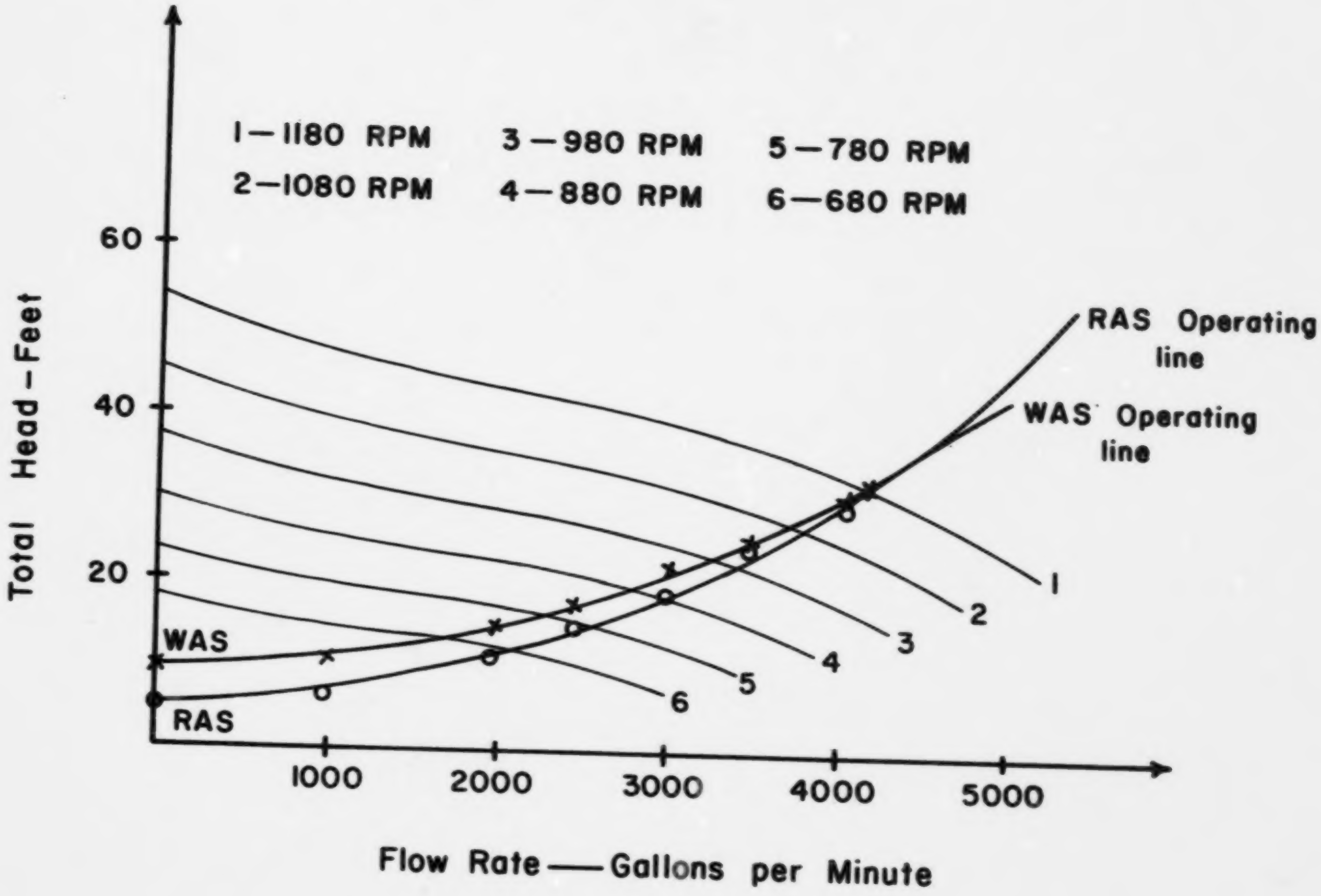

Figure C-1. Pump characteristic curves and operating lines for RAS and WAS pumps.

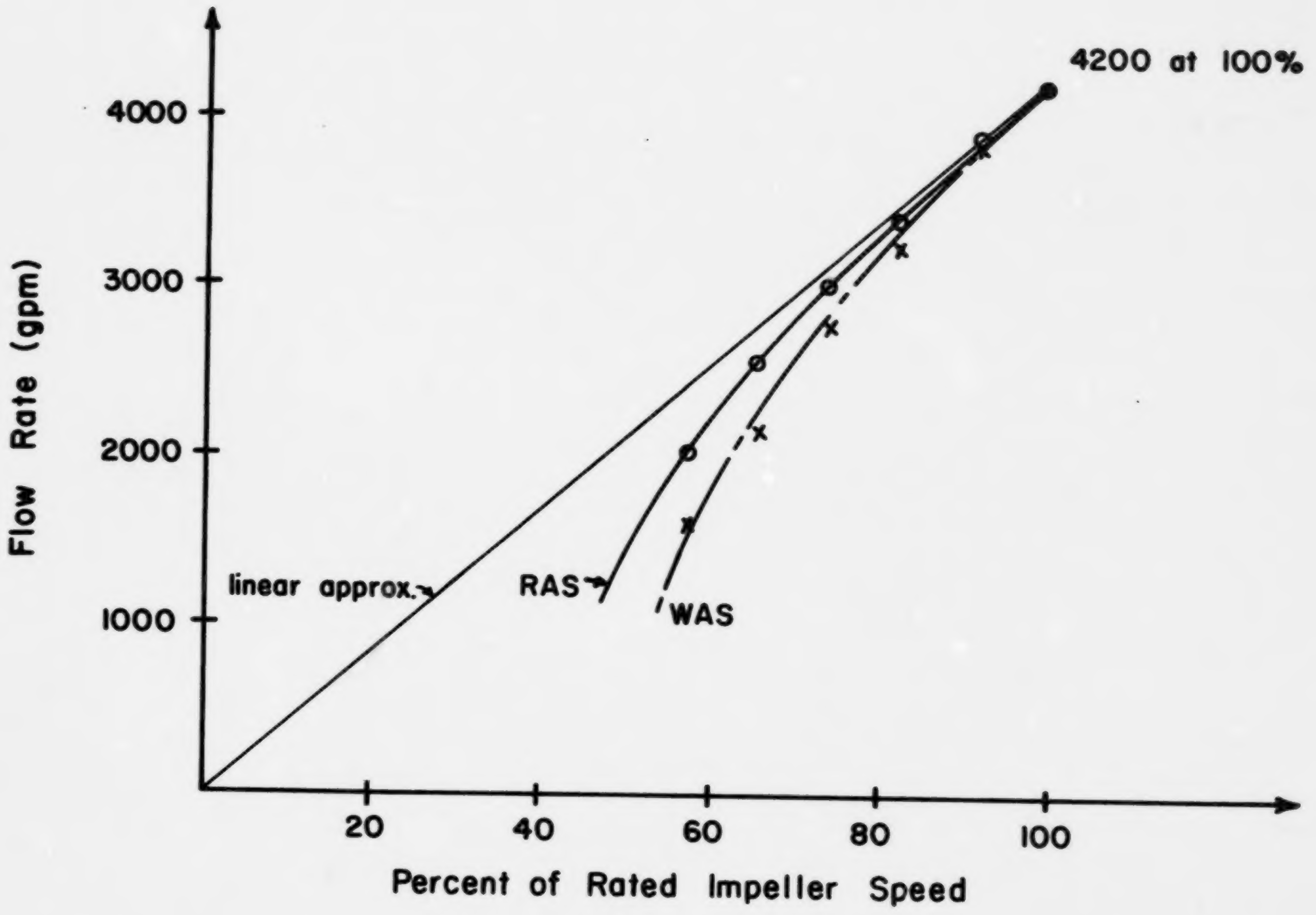

Figure C-2. Flow rate as a function of percent of rated impeller speed for RAS and WAS pumps.

RAS and WAS Flow Measurements Calculations

Static Head	WAS	RAS
Elevations (ft above datum)		
From	792.33	787.10
To	801.50	792.33
Difference	9.17	5.23
Dynamic Head (32.9 - Static Head)	23.7	27.7

Bernoulli's Equation:

$$\frac{V_1^2}{2g} + \frac{P_1}{\rho} + Z_1 + h_L = \frac{V_2^2}{2g} + \frac{P_2}{\rho} + Z_2 + h_p$$

Simplifications: $P_1 = P_2 = 1$ atm

$V_1 = V_2 = 0$

Therefore $(Z_1 - Z_2) + h_L = h_p$

This implies that the dynamic head is composed solely of head losses arising from piping, such as friction, valves, and so on. These all are proportional to $\frac{V^2}{2g}$ and, therefore, to Q^2 for a given pipe diameter. Thus:

$$h_p = (Z_1 - Z_2) + kQ^2$$

(Q in gpm, h_p in ft)

Using the given point as explained above:

WAS $32.9 = 9.17 + k(4200)^2$

RAS $32.9 = 5.23 + k(4200)^2$

$k_{WAS} = 1.35 \times 10^{-6}$

$k_{RAS} = 1.57 \times 10^{-6}$

Table C-1 develops the curve of h_p versus Q for the WAS and RAS pumps according to the above equation. These are plotted and identified in Figure C-1.

The intersection of the pump curve with the operating line determines the flow rate at the operating speed. These are plotted for the six given speeds, expressed as a percentage of the maximum speed for the WAS and RAS pumps in Figure C-2.

TABLE C-1. DEVELOPMENT OF TOTAL HEAD VERSUS FLOW RATE CURVE FOR WAS AND RAS PUMPS AT KOKOMO, INDIANA

Flow Rate (gpm)	Total Head (ft)	
	WAS	RAS
4200	32.9	32.9
4000	30.8	30.4
3500	25.7	24.5
3000	21.3	19.4
2500	17.6	15.0
2000	14.6	11.5
1000	10.5	6.8
0	9.2	5.2

VACUUM FILTER FILTRATE FLOW MEASUREMENT

The concept involved in measuring the stream flow is fairly simple: the mass of water in the filtrate stream must equal the difference in the mass of water in the vacuum filter feed and sludge cake streams. It is necessary to consider the solids concentration because they are not negligible at these high concentrations. The mathematical development is:

(1) $\#H_2O$ Filtrate = $\#H_2O$ Vacuum Filter Feed - $\#H_2O$ Cake

Water in vacuum filter feed

(2) $\#H_2O$ in VFF = $(Q_{VFF})\ (8.34)\ (S_{SL})\ (1 - fS)$

where Q_{VFF} = Volume of vacuum filter feed as determined by stroke counter on piston pump

8.32 = lbs sludge/gal for specific gravity of 1.0

S_{SL} = Specific gravity of sludge in VFF

fS = Fraction of solids in VFF

In general, when there are two constituents of different specific gravity:

$$(3)\ \frac{1}{S_1} = \frac{\%1}{S_1} + \frac{\%2}{S_2}$$

Therefore:

$$(4)\ \frac{1}{S_{SL}} = \frac{fS}{S_{SOL}} + \frac{(1-fS)}{1.0}$$

where fS = Fraction of solids

S_{SOL} = Specific gravity of the solids

1.0 = Specific gravity of water

Also:

$$(5)\ \frac{1}{S_{SOL}} = \frac{fVS}{1.0} + \frac{(1-fVS)}{2.5}$$

where fVS = Fraction volatile solids

1.0 = Specific gravity of volatile solids (1)

2.5 = Specific gravity of fixed solids (2)

From Kokomo lab data: fVS = 0.425, fS = 0.148.

Therefore:

$$(6)\ \frac{1}{S_{SOL}} = \frac{0.425}{1} + \frac{(1-0.425)}{2.5}$$

$$(7)\ S_{SOL} = 1.53$$

And:

$$(8)\ \frac{1}{S_{SL}} = \frac{0.148}{1.53} + \frac{(1-0.148)}{1.0}$$

$$(9)\ S_{SL} = 1.054$$

Therefore:

$$(10)\ \#H_2O \text{ in VFF} = (QVFF)\ (8.34)\ (1.054)\ (1 - \frac{0.148}{100})$$

(11) $\#H_2O$ in VFF = (Q_{VFF}) (7.49)

Water in filter cake:

(12) $\#H_2O$ Cake = (#sludge cake) $(1 - fS_C)$

where fS_C = Percent solids in filter cake

Volume of filtrate:

$$(13)\ Q_F = \frac{\#H_2O \text{ Filtrate}}{(1-fS)\ (8.34)\ (S_{SLF})}$$

where fS = Percent solids in filtrate

S_{SLF} = Specific gravity of filtrate

$$(14)\ \frac{1}{S_{SLF}} = \frac{fS_F}{S_{SOLF}} + \frac{(1-fS_F)}{1.0}$$

where fS_F = Fraction solids in filtrate

S_{SOLF} = Specific gravity of solids in filtrate

$$(15)\ \frac{1}{S_{SOLF}} = \frac{fVS_F}{1.0} + \frac{(1-fVS_F)}{2.5}$$

where fVS_F = Fraction volatile solids in filtrate

From Kokomo lab data: $fVS_F = 0.556$, $fS_F = 0.048$.

Therefore:

$$(16)\ \frac{1}{S_{SOLF}} = \frac{0.556}{1.0} + \frac{(1-0.556)}{2.5}$$

(17) $S_{SOLF} = 1.36$

And:

$$(18)\ \frac{1}{S_{SLF}} = \frac{0.048}{1.36} + \frac{(1-0.048)}{1.0}$$

(19) $S_{SLF} = 1.01$

Therefore:

$$(20)\quad Q_F = \frac{\#H_2O\ \text{Filtrate}}{(1-0.048)\ (8.34)\ (1.01)}$$

$$(21)\quad Q_F = \frac{\#H_2O\ \text{Filtrate}}{8.02}$$

where $\#H_2O$ Filtrate = $\#H_2O$ in VFF - $\#H_2O$ cake

Equation (11) Equation (12)

This calculation, Equation (21), was done each day the vacuum filter was on-line using the total feed volume, cake volume, and the average fraction of solids in the cake for that day.

APPENDIX D

POINT SOURCE MONITORING TABLES

Tables D-1 through D-38 contain flows and pollutant concentrations obtained in the point source monitoring program. Samples were collected for each trunkline at 2-hour intervals for three 24-hour periods.

TABLE D-1. POINT SOURCE 1, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
3-12-79	M	6P	0.042	0.002	0.005	0.08	0.02	1.01	0.071	<0.10
		8P	0.042	0.002	0.005	0.09	0.03	1.07	0.072	<0.10
		10P	0.042	0.002	0.007	0.08	0.05	0.97	0.056	<0.10
3-13-79	T	12A	0.044	0.001	0.013	0.06	0.04	0.83	0.033	<0.10
		2A	0.042	0.001	0.005	0.05	0.03	0.59	0.028	0.10
		4A	0.026	0.002	0.020	0.05	0.03	0.73	0.036	0.10
		6A	0.033	0.002	0.005	0.07	0.03	0.70	0.050	0.10
		8A	0.046	0.003	0.017	0.07	0.05	0.69	0.180	<0.10
		10A	0.046	0.002	0.005	0.07	0.03	0.68	0.050	0.10
		12P	0.046	0.001	0.006	0.07	0.03	0.70	0.034	<0.10
		2P	0.041	0.001	0.009	0.06	0.04	0.50	0.041	<0.10
		4P	0.046	0.001	0.008	0.05	0.03	0.51	0.023	<0.10
MEAN			0.041	0.002	0.009	0.07	0.03	0.75	0.050	0.10
STANDARD DEVIATION			0.006	0.001	0.005	0.01	0.01	0.18	0.024	0.0
MGD			0.496							
LBS/DAY				0.006	0.034	0.28	0.14	3.02	0.20	< 0.42

TABLE D-2. POINT SOURCE 1, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
3-13-79	T	6P	0.042	0.001	0.007	0.048	0.04	0.53	0.032	<0.10
		8P	0.018	0.001	0.012	0.047	0.03	0.45	0.064	<0.10
		10P	0.013	0.001	0.004	0.013	0.02	0.17	0.075	<0.10
3-14-79	W	12A	0.014	0.002	0.011	0.012	0.01	0.14	0.151	0.10
		2A	0.004	0.002	0.010	0.009	0.02	0.10	0.169	<0.10
		4A	0.033	0.001	0.006	0.059	0.04	0.37	0.077	<0.10
		6A	0.041	0.001	0.007	0.073	0.03	0.46	0.042	<0.10
		8A	0.042	0.001	0.004	0.057	0.03	0.37	0.061	<0.10
		10A	0.042	0.001	0.006	0.074	0.03	0.46	0.050	<0.10
		12P	0.042	0.001	0.005	0.070	0.03	0.49	0.049	<0.10
		2P	0.042	0.001	0.004	0.045	0.03	0.52	0.029	<0.10
		4P	0.046	0.001	0.004	0.055	0.02	0.52	0.033	0.13
MEAN			0.032	0.001	0.007	0.047	0.03	0.38	0.069	<0.10
STANDARD DEVIATION			0.015	0.001	0.003	0.023	0.01	0.15	0.045	0.01
MGD			0.379							
LBS/DAY				0.004	0.018	0.16	0.088	1.32	0.16	<0.33

TABLE D-3. POINT SOURCE 1, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
3-14-79	W	6P	0.041	0.001	0.009	0.06	0.02	0.54	0.029	0.12
		8P	0.020	0.001	0.004	0.03	0.02	0.45	0.073	0.10
		10P	0.013	0.001	0.006	0.01	0.02	0.14	0.045	0.10
3-15-79	TH	12A	0.033	0.001	0.009	0.06	0.02	0.44	1.172	<0.10
		2A	0.042	0.001	0.011	0.07	0.02	0.40	0.023	<0.10
		4A	0.042	0.001	0.010	0.07	0.02	0.44	0.017	0.10
		6A	0.041	0.001	0.006	0.06	0.02	0.43	0.030	<0.10
		8A	0.042	0.001	0.005	0.08	0.02	0.30	0.042	<0.10
		10P	0.042	0.001	0.014	0.07	0.02	0.60	0.025	<0.10
		12P	0.042	0.001	0.015	0.05	0.04	0.35	0.070	<0.10
		2P	0.042	0.001	0.014	0.05	0.03	0.35	0.016	<0.10
		4P	0.046	0.001	0.012	0.05	0.01	0.11	0.018	<0.10
MEAN			0.037	0.001	0.010	0.05	0.02	0.38	0.130	<0.10
STANDARD DEVIATION			0.010	0.000	0.004	0.02	0.01	0.14	0.329	0.01
MGD			0.446							
LBS/DAY				0.004	0.048	0.21	0.080	1.40	0.44	<0.38

TABLE D-4. POINT SOURCE 2, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-5-79	TH	12P	0.072	0.068	0.022	0.03	0.03	0.41	0.99	<0.10
		2P	0.072	0.032	0.018	0.02	0.01	0.21	0.92	<0.10
		4P	0.072	0.042	0.037	0.04	<0.01	0.16	0.56	0.11
		6P	0.072	0.035	0.016	0.02	<0.01	0.14	1.21	<0.10
		8P	0.072	0.048	0.016	0.03	<0.01	0.18	2.38	0.27
		10P	0.072	0.015	0.007	0.09	<0.01	0.25	0.69	0.10
7-6-79	FRI	12A	0.072	0.030	0.013	0.03	0.01	0.26	1.79	0.25
		2A	0.072	0.024	0.021	0.04	0.01	0.10	1.15	0.15
		4A	0.072	0.017	0.018	0.01	<0.01	0.08	1.01	0.23
		6A	0.072	0.010	0.015	0.01	<0.01	0.13	0.53	0.25
		8A	NF*	-	-	-	-	-	-	-
		10A	NF	-	-	-	-	-	-	-
MEAN			0.072	0.032	0.018	0.03	<0.02	0.197	1.12	<0.17
STANDARD DEVIATION			0.000	0.018	0.008	0.02	0.01	0.096	0.57	0.08
MGD			0.720							
LBS/DAY				0.19	0.11	0.19	<0.078	1.15	6.74	<0.99

*NF = No flow

TABLE D-5. POINT SOURCE 2, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
7-6-79	FRI	12P	0.027	0.038	0.024	0.04	0.01	0.20	1.04	<0.10
		2P	0.027	0.012	0.028	0.01	0.01	0.07	0.57	<0.10
		4P	0.027	0.007	0.014	0.01	<0.01	0.06	0.28	<0.10
		6P	0.027	0.005	0.014	0.01	<0.01	0.03	0.25	<0.10
		8P	NF*	-	-	-	-	-	-	-
		10P	NF	-	-	-	-	-	-	-
7-7-79	SAT	12A	0.027	0.012	0.011	0.01	<0.01	0.12	0.63	0.14
		2A	0.027	0.017	0.013	0.02	<0.01	0.18	0.90	0.10
		4A	0.027	0.020	0.014	0.02	<0.01	0.19	1.12	0.12
		6A	0.027	0.023	0.013	0.01	<0.01	0.12	1.22	0.11
		8A	0.027	0.023	0.013	0.01	<0.01	0.09	1.28	0.14
		10A	0.027	0.019	0.013	0.01	<0.01	0.10	1.00	0.14
MEAN			0.027	0.018	0.016	0.02	<0.01	0.12	0.82	<0.12
STANDARD DEVIATION			0.000	0.010	0.006	0.01	0.00	0.05	0.37	0.02
MGD			0.270							
LBS/DAY				0.044	0.032	0.034	<0.027	0.26	2.16	<0.25

---

*NF = No flow

TABLE D-6. POINT SOURCE 2, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-7-79	SAT	12P	0.027	0.014	0.012	0.01	<0.01	0.07	0.78	0.10
		2P	0.027	0.011	0.011	<0.01	<0.01	0.07	0.65	<0.10
		4P	0.027	0.011	0.011	0.01	<0.01	0.14	0.62	<0.10
		6P	0.027	0.010	0.012	0.02	<0.01	0.22	0.58	<0.10
		8P	0.027	0.013	0.018	0.01	<0.01	0.17	0.58	0.10
		10P	0.027	0.017	0.022	0.02	<0.01	0.14	0.82	<0.10
7-8-79	SUN	12A	0.027	0.023	0.010	0.01	<0.01	0.18	1.20	0.10
		2A	0.027	0.023	0.009	0.01	<0.01	0.14	0.87	0.10
		4A	0.027	0.023	0.010	0.02	<0.01	0.13	1.23	0.10
		6A	0.027	0.035	0.014	0.02	<0.01	0.16	1.53	0.12
		8A	0.027	0.028	0.010	0.01	<0.01	0.14	1.13	0.11
		10A	0.027	0.034	0.011	0.01	<0.01	0.13	1.28	0.10
MEAN			0.027	0.020	0.013	0.01	<0.01	0.14	0.93	<0.10
STANDARD DEVIATION			0.000	0.009	0.004	0.01	0.00	0.04	0.32	0.07
MGD			0.324							
LBS/DAY				0.054	0.034	0.034	<0.027	0.38	2.54	<0.28

TABLE D-7. POINT SOURCE 3, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-2-79	M	6P	0.173	0.050	0.015	0.04	<0.01	0.05	0.18	0.10
		8P	0.173	0.070	0.009	0.04	<0.01	0.06	0.23	<0.10
		10P	0.173	0.056	0.009	0.04	<0.01	0.05	0.20	<0.10
7-3-79	T	12A	0.173	0.020	0.010	0.03	<0.01	0.03	0.11	0.10
		2A	0.173	0.040	0.009	0.03	<0.01	0.03	0.14	<0.10
		4A	NF*	-	-	-	-	-	-	-
		6A	NF	-	-	-	-	-	-	-
		8A	NF	-	-	-	-	-	-	-
		10A	0.171	0.045	0.008	0.04	<0.01	0.06	0.21	0.10
		12P	0.171	0.068	0.009	0.06	0.01	4.34	0.39	<0.10
		2P	0.171	0.072	0.011	0.07	<0.01	3.92	0.46	0.13
		4P	0.171	0.076	0.008	0.07	<0.01	4.06	0.52	0.10
MEAN			0.172	0.055	0.010	0.05	<0.01	1.40	0.27	<0.10
STANDARD DEVIATION			0.11	0.018	0.002	0.02	0.00	2.03	0.15	0.01
MGD			1.549							
LBS/DAY				0.71	0.13	0.59	<0.13	17.98	3.49	<1.33

*No Flow

TABLE D-8. POINT SOURCE 3, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-3-79	T	6P	0.171	0.083	0.010	0.09	<0.01	5.96	0.59	0.14
		8P	0.171	0.066	0.008	0.06	<0.01	1.11	0.49	0.16
		10P	0.171	0.055	0.009	0.05	<0.01	3.50	0.42	0.15
7-4-79	W	12A	0.171	0.034	0.009	0.04	<0.01	3.47	0.26	0.13
		2A	0.171	0.076	0.007	0.06	0.01	3.45	0.55	0.16
		4A	0.171	0.052	0.008	0.05	<0.01	2.65	0.40	0.17
		6A	0.171	0.032	0.005	0.03	<0.01	3.44	0.21	0.21
		8A	0.171	0.034	0.013	0.04	<0.01	2.53	0.33	0.12
		10A	0.171	0.022	0.009	0.03	0.01	4.83	0.26	0.30
		12P	NF*	-	-	-	-	-	-	-
		2P	NF	-	-	-	-	-	-	-
		4P	NF	-	-	-	-	-	-	-
MEAN			0.171	0.050	0.009	0.05	<0.01	3.44	0.39	0.17
STANDARD DEVIATION			0.000	0.021	0.002	0.02	0.00	1.38	0.14	0.05
MGD			1.539							
LBS/DAY				0.65	0.12	0.64	<0.13	44.12	5.01	2.19

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*NF = No flow

TABLE D-9. POINT SOURCE 3, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-5-79	TH	8A	0.162	0.045	0.007	0.07	<0.01	0.39	0.36	0.10
		10A	0.162	0.070	0.010	0.06	<0.01	2.02	0.56	0.66
		12P	0.162	0.062	0.008	0.07	<0.01	1.19	0.49	0.33
		2P	0.162	0.058	0.006	0.06	<0.01	2.40	0.36	0.20
		4P	0.162	0.031	0.010	0.04	0.01	2.05	0.19	0.12
		6P	0.162	0.043	0.006	0.13	<0.01	1.26	0.23	0.68
		8P	0.162	0.055	0.011	0.12	<0.01	2.04	0.33	0.28
		10P	0.162	0.036	0.010	0.05	<0.01	1.42	0.21	0.23
7-6-79	FRI	12A	0.162	0.036	0.013	0.05	<0.01	2.62	0.21	0.24
		2A	0.162	0.067	0.010	0.05	<0.01	2.14	0.42	0.13
		4A	0.162	0.032	0.007	0.03	<0.01	1.88	0.19	0.10
		6A	0.162	0.032	0.014	0.02	0.24	3.24	0.18	0.23
MEAN			0.162	0.047	0.009	0.06	<0.03	1.89	0.31	0.28
STANDARD DEVIATION			0.000	0.014	0.003	0.03	0.07	0.75	0.13	0.20
MGD			1.944							
LBS/DAY				0.75	0.15	1.01	<0.47	30.60	5.04	≤4.46

TABLE D-10. POINT SOURCE 4 NORTH PLANT, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-21-79	M	6P	0.004	0.001	15.83	0.01	<0.01	148.96	0.40	<0.10
		8P	0.004	<0.001	13.36	0.01	<0.01	15.54	0.41	<0.10
		10P	0.004	<0.001	13.86	<0.01	0.01	16.83	0.16	<0.10
5-22-79		12A	0.004	<0.001	12.72	<0.01	<0.01	15.91	0.08	<0.10
		2A	0.004	<0.001	14.68	0.01	0.01	1.01	0.24	<0.10
		4A	0.004	<0.001	13.40	<0.01	<0.01	0.28	0.14	<0.10
		6A	0.004	0.001	15.96	<0.01	0.02	82.03	0.25	<0.10
		8A	0.004	0.002	23.64	0.01	0.03	78.16	0.28	<0.10
		10A	0.004	<0.001	16.63	<0.01	0.02	73.38	0.19	<0.10
		12P	0.004	<0.001	22.25	<0.01	0.03	75.49	0.37	<0.10
		2P	0.004	<0.001	27.41	<0.01	0.03	66.36	0.34	<0.10
		4P	0.004	<0.001	12.20	<0.01	0.03	49.19	0.18	<0.10
MEAN			0.004	<0.002	16.83	<0.01	≤0.02	51.93	0.25	<0.10
STANDARD DEVIATION			0.000	0.001	4.91	0.00	0.01	44.06	0.11	<0.10
MGD			0.048							
LBS/DAY				<0.001	6.21	<0.004	≤0.007	20.79	0.10	<0.040

TABLE D-11. POINT SOURCE 4 NORTH PLANT, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-15-79	T	6P	0.004	0.002	30.68	0.01	0.07	11.83	0.07	<0.10
		8P	0.004	0.002	36.34	0.02	0.01	15.18	0.08	<0.10
		10P	0.004	0.014	17.47	0.26	0.13	892.64	1.80	<0.10
5-16-79	W	12A	0.004	0.001	4.05	0.01	0.05	6.08	0.25	<0.10
		2A	0.004	0.001	1.04	0.01	0.03	0.79	0.04	<0.10
		4A	0.004	<0.001	0.66	0.01	0.02	0.36	0.02	<0.10
		6A	0.004	<0.001	0.70	0.04	0.02	0.19	0.02	<0.10
		8A	0.004	<0.001	1.59	0.01	0.02	0.93	0.02	<0.10
		10A	0.004	<0.001	19.01	<0.01	0.03	11.71	0.02	<0.10
		12P	0.004	<0.001	35.56	0.01	0.04	7.74	0.16	<0.10
		2P	0.004	<0.001	12.37	<0.01	0.02	8.95	0.05	<0.10
		4P	0.004	<0.001	2.16	0.01	0.02	1.78	0.13	<0.10
MEAN			0.004	<0.003	13.39	≤0.03	0.04	79.85	0.22	<0.10
STANDARD DEVIATION			0.000	0.004	14.20	0.07	0.03	256.00	0.50	<0.00
MGD			0.048							
LBS/DAY				<0.001	5.39	≤0.014	0.015	31.96	0.089	<0.040

TABLE D-12. POINT SOURCE 4 NORTH PLANT, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-16-79	W	6P	0.004	<0.001	7.75	0.01	0.02	6.22	0.29	<0.10
		8P	0.004	<0.001	10.62	0.01	0.03	5.84	0.52	<0.10
		10P	0.004	<0.001	7.40	0.02	0.02	4.09	0.30	<0.10
5-17-79	TH	12A	0.004	<0.001	5.09	0.01	0.03	0.10	0.61	<0.10
		2A	0.004	<0.001	1.40	<0.01	0.02	0.14	0.11	<0.10
		4A	0.004	<0.001	2.22	0.01	0.02	1.42	0.10	<0.10
		6A	0.004	<0.001	0.57	<0.01	0.02	0.09	0.05	<0.10
		8A	0.004	<0.001	15.68	0.01	0.03	3.27	0.13	<0.10
		10A	0.004	<0.001	3.56	0.01	0.02	2.08	0.12	<0.10
		12P	0.004	<0.001	13.45	0.01	0.02	1.81	0.16	<0.10
		2P	0.004	<0.001	64.94	0.02	0.05	1.40	0.25	<0.10
		4P	0.004	<0.001	14.53	0.01	0.01	7.95	0.07	<0.10
MEAN			0.004	<0.001	12.27	≤0.01	0.02	2.87	0.23	<0.10
STANDARD DEVIATION			0.000	0.000	17.38	0.004	0.01	2.63	0.18	0.00
MGD			0.048							
LBS/DAY				<0.001	4.91	≤0.004	0.010	1.14	0.090	<0.040

TABLE D-13. POINT SOURCE 4 SOUTH PLANT, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
5-21-79	M	6P	0.0035	<0.001	2.31	0.03	0.03	0.03	0.03	<0.10
		8P	0.0038	<0.001	16.85	0.10	0.10	0.05	0.16	<0.10
		10P	0.0031	<0.001	1.82	0.06	0.06	0.05	0.02	<0.10
		12A	0.0039	<0.001	1.72	0.02	0.02	0.03	0.02	<0.10
		2A	0.0041	<0.001	1.49	0.04	0.04	0.03	0.01	<0.10
		4A	0.0039	<0.001	1.63	0.04	0.04	0.02	0.01	<0.10
		6A	0.0038	<0.001	2.53	0.04	0.04	0.03	0.07	<0.10
		8A	0.0041	<0.001	1.46	<0.01	0.01	0.03	0.01	<0.10
		10A	0.0042	<0.001	1.44	0.04	0.04	0.04	0.01	<0.10
		12P	0.0042	<0.001	0.20	0.11	0.11	0.05	0.01	<0.10
		2P	0.0044	<0.001	<0.01	0.33	0.33	0.43	1.45	<0.10
		4P	0.0036	<0.001	18.24	0.04	0.04	0.04	0.11	<0.10
MEAN			0.0039	<0.001	≤4.14	≤0.07	0.07	0.08	0.16	0.10
STANDARD DEVIATION			0.0004	0.000	6.31	0.09	0.07	0.11	0.41	0.00
MGD			0.0466							
LBS/DAY				<0.001	≤1.54	≤0.029	0.028	0.029	0.067	<0.039

TABLE D-14. POINT SOURCE 4 SOUTH PLANT, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-15-79	T	6P	0.0039	0.003	2.20	0.02	0.10	0.29	0.01	<0.10
		8P	0.0036	0.003	2.77	0.02	0.02	0.19	0.01	<0.10
		10P	0.0036	0.003	1.90	0.02	0.11	0.16	0.01	<0.10
5-16-79	W	12A	0.0041	0.003	1.61	0.02	0.09	0.14	0.01	<0.10
		2A	0.0043	0.003	1.50	0.02	0.14	0.27	0.01	<0.10
		4A	0.0041	0.003	2.71	0.02	0.13	0.16	0.02	<0.10
		6A	0.0040	0.002	1.54	0.20	0.08	0.11	0.01	<0.10
		8A	0.0030	0.003	1.18	0.02	0.06	0.10	0.01	<0.10
		10A	0.0030	0.003	1.60	0.02	0.01	0.12	0.02	<0.10
		12P	0.0034	0.003	0.39	0.02	0.07	0.13	0.01	<0.10
		2P	0.0031	0.003	2.81	0.02	0.08	0.17	0.01	<0.10
		4P	0.0037	<0.001	7.57	0.02	0.34	0.06	0.04	<0.10
MEAN			0.0037	≤0.003	2.31	0.04	0.10	0.16	0.01	<0.10
STANDARD DEVIATION			0.0004	0.001	1.80	0.05	0.08	0.07	0.01	0.00
MGD			0.0438							
LBS/DAY				≤0.001	0.85	0.013	0.039	0.059	0.005	<0.037

TABLE D-15. POINT SOURCE 4 SOUTH PLANT, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-16-79	W	6P	0.0038	0.001	8.49	0.02	0.08	0.08	0.03	<0.10
		8P	0.0036	0.001	0.67	0.02	0.07	0.09	0.01	<0.10
		10P	0.0037	0.001	6.73	0.01	0.09	0.09	0.02	<0.10
5-17-79	TH	12A	0.0039	0.001	40.43	0.01	0.11	0.19	0.02	<0.10
		2A	0.0037	0.001	13.14	0.01	0.11	0.07	0.02	<0.10
		4A	0.0040	0.001	30.81	0.01	0.05	0.07	0.01	<0.10
		6A	0.0038	0.001	21.83	0.01	0.08	0.07	0.01	<0.10
		8A	0.0037	0.001	18.67	0.01	0.08	0.05	0.01	<0.10
		10A	0.0042	0.001	37.86	0.01	0.04	0.06	0.02	<0.10
		12P	0.0036	0.001	34.14	0.01	0.06	0.07	0.01	<0.10
		2P	0.0036	0.001	2.61	0.01	0.06	0.07	0.01	<0.10
		4P	0.0036	0.001	4.14	0.01	0.19	0.07	0.02	<0.10
MEAN			0.0038	0.001	18.29	0.01	0.09	0.08	0.02	<0.10
STANDARD DEVIATION			0.0001	0.000	14.48	0.004	0.04	0.04	0.01	0.00
MGD			0.0452							
LBS/DAY				<0.001	7.06	0.004	0.032	0.031	0.006	0.038

TABLE D-16. POINT SOURCE 5, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-9-79	M	6P	0.0145	0.638	39.47	1.97	0.07	0.65	0.55	0.30
		8P	0.0122	0.116	4.86	3.68	0.02	0.40	0.13	0.12
		10P	0.0059	0.053	5.21	0.96	0.02	0.34	0.39	1.32
7-10-79	T	12A	0.0090	0.181	20.28	18.79	0.12	0.34	0.55	1.04
		2A	0.0097	0.096	33.26	3.16	0.05	0.35	0.35	<0.10
		4A	0.0082	0.126	54.38	2.70	0.05	1.75	0.39	0.10
		6A	0.0052	0.080	43.53	1.85	0.03	0.55	0.30	0.10
		8A	0.0130	0.453	34.10	2.86	0.14	1.98	0.69	0.10
		10A	0.0166	0.163	32.95	15.02	0.07	0.67	0.33	0.22
		12P	0.0077	0.184	39.90	7.46	0.05	1.41	0.26	0.19
		2P	0.0054	0.547	26.63	4.59	0.10	3.18	0.87	3.80
		4P	0.0102	2.071	138.24	6.40	0.06	2.66	3.36	0.25
MEAN			0.0098	0.392	39.40	5.79	0.07	1.19	0.68	0.64
STANDARD DEVIATION			0.0037	0.564	34.39	5.57	0.04	0.99	0.87	1.07
MGD			0.235							
LBS/DAY				0.41	39.12	6.21	0.067	1.10	0.67	≤0.45

TABLE D-17. POINT SOURCE 5, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
7-10-79	T	6P	0.0122	0.874	43.25	1.53	0.09	2.67	1.22	0.35
		8P	0.0108	0.107	14.98	1.52	0.05	0.89	0.32	0.18
		10P	0.0103	0.069	18.80	1.22	0.05	0.85	0.29	0.75
7-11-79	W	12A	0.0083	0.040	15.06	0.92	0.02	0.88	0.17	0.32
		2A	0.0070	0.069	59.22	0.88	0.06	0.36	0.40	0.38
		4A	0.0052	0.069	537.12	0.94	0.03	0.55	0.32	1.11
		6A	0.0040	0.076	79.95	0.96	0.05	0.42	0.29	0.39
		8A	0.0069	0.889	43.56	0.55	0.22	4.79	0.85	0.28
		10A	0.0111	1.213	33.11	18.05	0.13	3.93	1.43	0.52
		12P	0.0089	0.288	38.78	5.44	0.06	1.32	0.73	0.39
		2P	0.0108	0.149	27.59	6.98	0.06	1.03	0.51	0.56
		4P	0.0041	1.415	898.54	3.84	0.19	2.93	2.79	1.87
MEAN				0.438	151.24	3.57	0.08	1.72	0.78	0.59
STANDARD DEVIATION				0.510	276.24	5.01	0.06	1.49	0.75	0.47
MGD			0.213							
LBS/DAY				0.36	79.93	3.45	0.067	1.48	0.61	0.43

TABLE D-18. POINT SOURCE 5, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
7-11-79	W	6P	0.0114	0.694	41.39	1.92	0.10	1.63	0.98	1.74
		8P	0.0114	0.191	8.18	2.76	0.14	1.64	1.14	9.24
		10P	0.0089	0.140	8.12	2.59	0.04	0.56	0.94	8.72
7-12-79	TH	12A	0.0087	1.341	111.48	11.55	2.28	5.41	2.85	4.73
		2A	0.0074	0.108	81.29	2.59	0.38	0.85	1.15	1.88
		4A	0.0055	0.066	447.29	1.69	0.19	2.14	0.64	4.08
		6A	0.0046	0.109	74.15	1.85	0.19	0.83	0.70	0.16
		8A	0.0116	1.265	131.02	3.14	0.51	4.14	1.74	4.55
		10A	0.0199	0.863	42.72	4.81	0.17	3.39	0.96	0.49
		12P	0.0147	1.092	40.58	3.91	0.31	5.89	1.22	6.22
		2P	0.0146	1.189	46.59	6.08	0.54	7.14	1.52	0.38
		4P	0.0132	1.739	528.39	5.31	0.22	2.59	3.26	0.50
MEAN			0.0109	0.733	130.10	4.02	0.42	3.02	1.43	3.55
STANDARD DEVIATION			0.004	0.595	171.97	2.77	0.61	2.19	0.83	3.24
MGD			0.264							
LBS/DAY				0.94	130.36	4.69	0.51	3.77	1.63	3.72

TABLE D-19. POINT SOURCE 6 (SOUTH), SAMPLING DAY ONE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-24-79	T	6P	0.032	0.003	0.035	0.14	0.37	280.55	0.03	0.23
		8P	0.032	0.003	0.052	0.15	0.36	395.09	0.02	0.23
		10P	0.032	0.003	0.037	0.16	0.39	342.26	0.28	0.25
4-25-79	W	12A	0.032	0.004	0.065	0.16	0.53	611.45	0.22	0.26
		2A	0.032	0.003	0.038	0.11	0.30	347.04	0.11	0.40
		4A	0.032	0.003	0.042	0.13	0.35	453.74	0.13	0.35
		6A	0.032	0.003	0.070	0.20	0.46	459.16	0.15	0.28
		8A	0.032	0.003	0.061	0.12	0.21	596.95	0.14	<0.10
		10A	0.032	0.003	0.041	0.13	0.24	247.82	0.16	0.37
		12P	0.032	0.003	0.033	0.10	0.11	159.25	0.16	0.18
		2P	0.032	0.003	0.020	0.10	0.22	118.33	0.18	<0.10
		4P	0.032	0.002	0.010	0.05	0.08	128.41	0.09	0.10
MEAN			0.032	0.003	0.092	0.13	0.30	345.01	0.14	0.24
STANDARD DEVIATION			0.000	0.001	0.018	0.04	0.13	167.40	0.07	0.10
MGD			0.384							
LBS/DAY				0.010	0.14	0.41	0.97	1104.90	0.45	<0.76

TABLE D-20. POINT SOURCE 6 (SOUTH), SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-25-79	W	6P	0.032	0.002	0.001	0.07	0.06	62.76	0.07	<0.10
		8P	0.032	0.001	0.001	0.06	0.05	61.69	0.05	<0.10
		10P	0.032	0.001	0.002	0.04	0.03	32.78	0.05	<0.10
4-26-79	Th	12A	0.032	0.001	0.004	0.05	0.03	27.50	0.05	<0.10
		2A	0.032	0.002	0.025	0.13	0.12	184.27	0.08	0.10
		4A	0.032	0.001	0.012	0.08	0.08	175.43	0.08	0.10
		6A	0.032	0.001	0.003	0.04	0.02	26.98	0.06	<0.10
		8A	0.032	<0.001	0.013	0.09	0.03	39.41	0.06	<0.10
		10A	0.032	<0.001	0.004	0.04	0.05	55.12	0.08	<0.10
		12P	0.032	<0.001	0.004	0.03	0.04	62.90	0.06	0.10
		2P	0.032	0.001	0.004	0.02	0.02	26.41	0.04	<0.10
		4P	0.032	0.001	0.009	0.07	0.07	33.13	0.12	<0.10
MEAN			0.032	<0.001	0.007	0.06	0.05	65.70	0.07	<0.10
STANDARD DEVIATION			0.000	0.001	0.007	0.03	0.03	55.25	0.02	0.00
MGD			0.384							
LBS/DAY				≤0.004	0.022	0.19	0.16	210.40	0.21	<0.32

TABLE D-21. POINT SOURCE 6 (SOUTH), SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-26-79	TH	6P	0.032	0.001	0.008	0.05	0.07	37.27	0.09	<0.10
		8P	0.032	<0.001	0.008	0.07	0.09	5.99	0.14	<0.10
		10P	0.032	<0.001	0.007	0.07	0.07	8.98	0.11	<0.10
5-4-79	FRI	12A	0.032	0.003	0.020	0.10	0.08	55.87	0.14	<0.10
		2A	0.032	0.003	0.021	0.11	0.07	89.79	0.15	<0.10
		4A	0.032	0.003	0.015	0.09	0.06	55.16	0.12	<0.10
		6A	0.032	0.003	0.011	0.06	0.06	98.71	0.10	<0.10
		8A	0.032	0.003	0.037	0.14	0.15	98.90	0.60	<0.10
		10A	0.032	0.003	0.019	0.06	0.09	105.65	0.12	0.13
		12P	0.032	0.003	0.022	0.08	0.09	106.75	0.14	<0.10
		2P	0.032	0.003	0.013	0.05	0.06	120.16	0.07	0.10
		4P	0.032	0.004	0.024	0.08	0.13	114.25	0.14	<0.10
MEAN			0.032	≤0.003	0.017	0.08	0.09	74.79	0.16	<0.10
STANDARD DEVIATION			0.000	0.001	0.009	0.03	0.03	40.66	0.14	0.01
MGD			0.384							
LBS/DAY				≤0.008	0.055	0.27	0.27	239.52	0.51	<0.33

TABLE D-22. POINT SOURCE 7, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-21-79	M	6P	0.006	<0.001	0.025	0.20	0.05	26.34	1.38	<0.10
		8P	0.006	<0.001	0.020	0.11	0.03	16.65	1.00	<0.10
		10P	0.006	<0.001	0.023	0.15	0.02	15.90	0.92	<0.10
5-22-79	T	12A	0.006	<0.001	0.264	1.93	0.14	33.95	9.87	<0.10
		2A	0.006	<0.001	0.302	2.24	0.17	25.23	12.64	<0.10
		4A	0.006	<0.001	0.265	1.48	0.13	30.95	8.85	<0.10
		6A	0.006	<0.001	0.289	1.84	0.15	4.74	11.15	<0.10
		8A	0.006	<0.001	0.022	0.11	0.03	19.39	0.93	<0.10
		10A	0.006	<0.001	0.020	0.10	0.01	11.01	0.64	<0.10
		12P	0.006	<0.001	0.014	0.13	0.01	1.39	0.14	<0.10
		2P	0.006	<0.001	0.011	<0.01	<0.01	0.45	0.02	<0.10
		4P	0.006	<0.001	0.027	0.11	0.04	84.41	0.93	<0.10
MEAN			0.006	<0.001	0.11	≤0.83	≤0.07	16.91	4.32	<0.10
STANDARD DEVIATION			0.000	0.000	0.13	0.92	0.07	11.61	5.09	0.00
MGD			0.072							
LBS/DAY				<0.001	1.31	≤1.12	≤0.039	13.53	2.43	<0.060

TABLE D-23. POINT SOURCE 7, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN¯
5-23-79	W	6P	0.006	<0.001	0.082	0.39	0.09	112.51	3.62	<0.10
		8P	0.006	<0.001	0.088	0.46	0.12	124.14	2.42	<0.10
		10P	0.006	<0.001	0.133	0.84	0.10	120.99	4.37	<0.10
5-24-79	TH	12A	0.006	<0.001	0.112	0.69	0.08	57.40	3.42	<0.10
		2A	0.006	<0.001	0.093	0.55	0.06	109.48	2.62	<0.10
		4A	0.006	<0.001	0.102	0.65	0.07	117.67	3.21	<0.10
		6A	0.006	<0.001	0.100	0.59	0.07	111.57	2.88	<0.10
		8A	0.006	<0.001	0.063	0.29	0.09	104.92	1.52	<0.10
		10A	0.006	<0.001	0.041	0.07	0.11	77.84	2.02	<0.10
		12P	0.006	<0.001	0.009	0.07	0.04	71.34	0.69	<0.10
		2P	0.006	<0.001	0.017	0.11	0.04	74.79	0.88	<0.10
		4P	0.006	<0.001	0.138	0.89	0.11	145.25	4.71	<0.10
MEAN			0.006	<0.001	0.081	0.47	0.08	102.33	2.69	<0.10
STANDARD DEVIATION			0.000	0.000	0.044	0.30	0.03	26.09	1.27	0.00
MGD			0.072							
LBS/DAY				<0.001	0.045	0.26	0.045	56.49	1.46	<0.060

TABLE D-24. POINT SOURCE 7, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-29-79	T	6P	0.006	<0.001	0.014	0.10	0.04	199.03	0.98	<0.10
		8P	0.006	<0.001	0.012	0.07	0.02	81.25	0.44	<0.10
		10P	0.006	<0.001	0.016	0.10	0.02	84.11	0.59	<0.10
5-30-79	W	12A	0.006	<0.001	0.124	0.78	0.12	66.61	5.33	<0.10
		2A	0.006	<0.001	0.221	0.92	0.04	85.59	2.46	<0.10
		4A	0.006	<0.001	0.214	0.90	0.03	56.13	0.02	<0.10
		6A	0.006	<0.001	0.200	0.82	0.03	46.67	0.01	<0.10
		8A	0.006	<0.001	0.230	0.93	0.04	52.53	0.02	<0.10
		10A	0.006	<0.001	0.204	0.73	0.04	46.40	0.01	<0.10
		12P	0.006	<0.001	0.158	0.60	0.05	46.18	0.01	<0.10
		2P	0.006	<0.001	0.163	0.61	0.05	22.04	0.01	<0.10
		4P	0.006	<0.001	0.085	0.13	0.03	19.54	0.01	<0.10
MEAN			0.006	<0.001	0.147	0.56	0.04	73.80	0.82	<0.10
STANDARD DEVIATION			0.000	0.000	0.076	0.35	0.03	42.19	1.59	0.00
MGD			0.072							
LBS/DAY				<0.001	0.082	0.33	0.026	43.56	0.49	<0.060

TABLE D-25. POINT SOURCE 8, SAMPLING DAY ONE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-16-79	M	6P	0.022	<0.001	0.025	0.05	0.03	0.12	0.15	<0.10
		8P	0.022	<0.001	0.086	0.12	0.06	0.29	0.25	<0.10
		10P	0.022	<0.001	0.047	0.07	0.05	0.02	0.20	<0.10
4-17-79	T	12A	0.022	<0.001	0.031	0.05	0.03	0.01	0.19	<0.10
		2A	0.022	<0.001	0.016	0.02	0.02	0.01	0.15	<0.10
		4A	0.022	<0.001	0.011	0.01	0.02	0.01	0.18	<0.10
		6A	0.022	<0.001	0.007	0.01	0.01	0.02	0.18	<0.10
		8A	0.022	<0.001	0.011	0.01	0.01	0.02	0.20	<0.10
		10A	0.022	<0.001	0.015	0.02	0.02	0.01	0.18	<0.10
		12P	0.022	<0.001	0.020	0.03	0.03	0.01	0.13	<0.10
		2P	0.022	<0.001	0.039	0.07	0.05	0.02	0.81	<0.10
		4P	0.022	<0.001	0.035	0.06	0.05	0.05	0.40	<0.10
MEAN			0.022	<0.001	0.033	0.03	0.03	0.04	0.25	<0.10
STANDARD DEVIATION			0.000	0.000	0.024	0.02	0.02	0.08	0.19	0.00
MGD			0.264							
LBS/DAY				<0.001	0.063	0.095	0.070	0.14	0.55	<0.22

TABLE D-26. POINT SOURCE 8, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-17-79	T	6P	0.022	<0.001	0.006	0.26	0.04	0.54	0.26	<0.10
		8P	0.022	<0.001	0.016	0.01	0.01	0.16	0.08	<0.10
		10P	0.022	<0.001	0.022	0.02	0.02	0.29	0.12	<0.10
4-18-79	W	12A	0.022	<0.001	0.019	0.02	0.01	0.47	0.12	<0.10
		2A	0.022	<0.001	0.014	0.03	0.01	0.02	0.11	<0.10
		4A	0.022	<0.001	0.021	0.06	0.01	0.04	0.14	<0.10
		6A	0.022	<0.001	0.009	0.01	0.01	0.21	0.14	<0.10
		8A	0.022	<0.001	0.007	<0.01	0.01	8.49	0.14	<0.10
		10A	0.022	<0.001	0.011	<0.01	0.01	1.03	0.19	<0.10
		12P	0.022	<0.001	0.012	0.01	0.01	0.31	0.13	<0.10
		2P	0.022	<0.001	0.019	0.03	0.01	0.45	0.11	<0.10
		4P	0.024	<0.001	0.011	0.01	0.01	0.40	0.09	<0.10
MEAN			0.022	<0.001	0.014	≤0.04	0.01	1.03	0.14	<0.10
STANDARD DEVIATION			0.001	0.000	0.005	0.07	0.01	2.36	0.05	0.00
MGD			0.266							
LBS/DAY				<0.001	0.031	≤0.088	0.030	2.28	0.30	<0.22

TABLE D-27. POINT SOURCE 8, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
4-18-79	W	6P	0.024	<0.001	0.014	0.02	0.01	0.29	0.10	<0.10
		8P	0.024	<0.001	0.010	<0.01	0.01	0.27	0.13	<0.10
		10P	0.024	<0.001	0.007	<0.01	0.01	0.24	0.15	<0.10
4-19-79		12A	0.024	<0.001	0.013	0.02	0.01	0.25	0.13	<0.10
		2A	0.024	<0.001	0.008	<0.01	0.01	0.25	0.17	<0.10
		4A	0.024	<0.001	0.005	<0.01	0.01	0.17	0.11	<0.10
		6A	0.024	<0.001	0.004	<0.01	0.01	0.15	0.12	<0.10
		8A	0.024	<0.001	0.006	<0.01	0.01	0.22	0.17	<0.10
		10A	0.024	<0.001	0.007	<0.01	0.01	0.09	0.12	<0.10
		12P	0.024	<0.001	0.018	0.01	0.03	0.27	0.16	<0.10
		2P	0.024	<0.001	0.011	0.01	0.02	0.28	0.12	<0.10
		4P	0.024	<0.001	0.008	0.01	0.01	6.59	0.02	<0.10
MEAN			0.024	<0.001	0.009	<0.01	0.01	0.76	0.13	<0.10
STANDARD DEVIATION			0.000	<0.000	0.004	0.01	0.01	1.83	0.04	0.00
MGD			0.288							
LBS/DAY				<0.001	0.022	<0.028	0.027	1.82	0.30	<0.24

TABLE D-28. POINT SOURCE 9, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
3-19-79	M	6P	0.028	0.001	0.14	0.30	0.01	0.19	0.07	0.10
		8P	0.028	<0.001	0.30	0.59	0.01	0.12	0.07	<0.10
		10P	0.028	<0.001	0.08	6.19	0.01	0.05	0.03	0.24
3-20-79	T	12A	0.028	<0.001	0.16	0.47	<0.01	0.11	0.06	0.10
		2A	0.028	0.001	0.05	0.09	<0.01	0.08	0.02	0.10
		4A	0.028	<0.001	0.13	0.24	0.01	0.11	0.04	0.10
		6A	0.028	<0.001	0.08	0.24	0.01	0.11	0.04	0.10
		8A	0.028	<0.001	0.33	0.39	0.01	0.10	0.06	<0.10
		10A	0.028	<0.001	0.15	18.49	0.01	0.08	0.05	<0.10
		12P	0.028	<0.001	0.08	0.77	0.01	0.15	0.10	<0.10
		2P	0.028	0.001	0.06	7.42	0.01	0.08	0.03	0.12
		4P	0.028	<0.001	0.11	0.30	0.01	0.23	0.11	0.10
MEAN			0.028	<0.001	0.14	2.96	<0.01	0.12	0.05	<0.11
STANDARD DEVIATION			0.000	0.000	0.09	5.49	0.00	0.05	0.03	0.40
MGD			0.335							
LBS/DAY				<0.003	0.39	8.25	<0.028	0.33	0.16	<0.32

TABLE D-29. POINT SOURCE 9, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
3-20-79	T	6P	0.028	0.001	0.03	13.12	0.01	0.10	0.04	<0.10
		8P	0.028	<0.001	0.02	0.33	0.01	0.12	0.08	<0.10
		10P	0.028	<0.001	0.07	13.31	0.01	0.07	0.07	<0.10
3-21-79	W	12A	0.028	<0.001	0.01	0.15	0.01	0.08	0.05	<0.10
		2A	0.028	0.002	0.48	13.50	0.01	0.18	0.12	<0.10
		4A	0.028	0.002	0.33	0.35	0.01	0.20	0.13	0.10
		6A	0.028	0.003	0.17	0.31	0.01	0.18	0.10	<0.10
		8A	0.028	0.001	0.06	1.07	0.01	0.26	0.16	<0.10
		10A	0.028	<0.001	0.08	0.43	0.01	0.18	0.10	<0.10
		12P	0.028	<0.001	0.09	0.83	0.01	0.17	0.11	<0.10
		2P	0.028	<0.001	0.06	0.28	0.01	0.17	0.10	<0.10
		4P	0.028	0.001	0.17	6.00	0.01	0.15	0.06	<0.10
MEAN			0.028	<0.002	0.13	4.14	0.01	0.15	0.09	<0.10
STANDARD DEVIATION			0.000	0.001	0.13	5.29	0.00	0.05	0.03	0.00
MGD			0.335							
LBS/DAY				<0.004	0.36	11.57	0.028	0.42	0.26	<0.28

TABLE D-30. POINT SOURCE 9, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
3-21-79	W	6P	0.028	0.001	0.17	2.32	0.01	0.13	0.10	<0.10
		8P	0.028	<0.001	0.23	5.33	0.01	0.09	0.07	<0.10
		10P	0.028	0.001	0.32	0.45	0.01	0.15	0.11	<0.10
3-22-79	TH	12A	0.028	0.001	0.05	0.40	0.01	0.16	0.06	<0.10
		2A	0.028	0.002	0.60	0.44	0.01	0.24	0.14	<0.10
		4A	0.028	0.002	0.32	0.36	0.01	0.18	0.15	<0.10
		6A	0.028	0.002	0.20	0.28	0.01	0.11	0.11	<0.10
		8A	0.028	<0.001	0.11	0.71	0.01	0.13	0.09	<0.10
		10A	0.028	<0.001	0.24	5.66	0.01	0.26	0.11	0.10
		12P	0.028	0.001	0.15	3.16	0.01	0.07	0.07	0.10
		2P	0.028	0.001	0.09	1.90	0.01	0.14	0.08	0.10
MEAN			0.028	<0.002	0.225	1.91	0.01	0.15	0.09	<0.10
STANDARD DEVIATION			0.000	0.001	0.15	2.01	0.00	0.06	0.02	0.00
MGD			0.335							
LBS/DAY				<0.004	0.63	5.34	0.028	0.42	0.28	<0.28

TABLE D-31. POINT SOURCE 10, SAMPLING DAY ONE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
3-20-79	T	6P	0.0048	0.001	0.005	0.12	<0.01	0.46	0.03	<0.10
		8P	0.0048	0.001	0.004	0.18	<0.01	1.66	0.05	<0.10
		10P	0.0048	0.002	0.080	0.42	0.01	0.16	0.12	<0.10
3-21-79	W	12A	0.0048	0.001	0.002	0.15	<0.01	0.98	0.03	<0.10
		2A	0.0048	0.001	0.002	0.14	0.01	1.43	0.04	<0.10
		4A	0.0048	0.001	0.016	0.20	0.01	1.20	0.06	0.11
		6A	0.0048	0.001	0.040	0.33	0.01	4.13	0.15	<0.10
		8A	0.0048	0.001	0.007	0.42	0.01	1.15	0.04	<0.10
		10A	0.0048	0.002	0.006	0.12	0.01	1.20	0.04	<0.10
		12P	0.0048	0.002	0.005	0.09	<0.01	0.78	0.04	<0.10
		2P	0.0048	0.001	0.004	0.08	<0.01	0.55	0.03	<0.10
		4P	0.0048	0.001	0.027	0.15	0.01	0.57	0.04	<0.10
MEAN			0.0048	0.001	0.016	0.20	<0.01	1.19	0.05	<0.10
STANDARD DEVIATION			0.0000	0.001	0.023	0.12	0.00	1.94	0.04	0.01
MGD			0.058							
LBS/DAY				<0.001	0.008	0.10	<0.005	0.56	0.03	<0.048

TABLE D-32. POINT SOURCE 10, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
3-21-79	W	6P	0.0048	0.001	0.003	0.09	<0.01	0.48	0.03	<0.10
		8P	0.0048	0.003	0.036	0.23	0.01	3.39	0.15	<0.10
		10P	0.0048	0.002	0.084	0.42	0.01	4.08	0.20	<0.10
3-22-79	TH	12A	0.0048	0.001	0.003	0.17	0.01	1.54	0.05	<0.10
		2A	0.0048	0.002	0.133	0.47	0.01	3.86	0.19	<0.10
		4A	0.0048	0.001	0.037	0.20	0.01	1.62	0.07	<0.10
		6A	0.0048	0.001	0.009	0.15	0.01	1.83	0.04	<0.10
		8A	0.0048	0.001	0.006	0.17	0.01	2.99	0.09	<0.10
		10A	0.0048	0.003	0.125	0.48	0.01	6.03	0.19	<0.10
		12P	0.0048	0.002	0.052	0.31	0.01	2.41	0.20	<0.10
		2P	0.0048	0.001	0.019	0.17	0.01	1.67	0.07	<0.10
		4P	0.0048	0.001	0.012	0.15	0.01	1.97	0.08	<0.10
MEAN			0.0048	0.002	0.043	0.25	≤0.01	2.65	0.113	<0.10
STANDARD DEVIATION			0.0000	0.001	0.047	0.14	0.00	1.50	0.67	0.00
MGD			0.058							
LBS/DAY				0.001	0.020	0.12	≤0.003	1.28	0.054	<0.048

TABLE D-33. POINT SOURCE 11, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-1-79	T	6A	0.0056	0.013	0.016	0.01	0.07	0.51	0.10	0.13
		8A	0.0056	0.015	0.029	0.04	0.93	0.69	0.17	0.14
		10A	0.0056	0.017	0.018	0.01	0.75	0.74	0.25	0.11
		12P	0.0056	0.003	0.001	<0.01	0.13	0.10	0.29	<0.10
		2P	0.0056	0.007	0.010	0.01	0.23	0.26	0.28	0.10
		4P	0.0056	0.025	0.036	0.02	1.42	0.92	0.37	<0.10
		6P	0.0056	0.015	0.020	0.01	0.07	0.50	0.22	<0.10
		8P	0.0056	0.009	0.020	<0.01	0.62	0.35	0.21	0.10
MEAN			0.0056	0.013	0.019	<0.02	0.53	0.51	0.24	<0.11
STANDAND DEVIATION				0.007	0.011	0.02	0.49	0.27	0.08	0.02
MGD			0.0445							
LBS/DAY				0.005	0.007	<0.006	0.20	0.19	0.088	<0.041

TABLE D-34. POINT SOURCE 11, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-2-79	W	6A	0.0036	0.005	0.007	0.02	0.40	0.19	0.15	<0.10
		8A	0.0036	0.006	0.008	0.02	0.60	0.26	0.17	<0.10
		10A	0.0036	0.011	0.007	0.01	1.12	0.27	0.17	<0.10
		12P	0.0036	0.032	0.007	0.01	2.70	0.66	0.46	<0.10
		2P	0.0036	0.016	0.027	0.02	1.94	0.45	0.36	<0.10
		4P	0.0036	0.016	0.037	0.04	3.02	0.51	0.36	0.10
		6P	0.0036	0.018	0.002	0.03	3.46	0.68	0.42	<0.10
		8P	0.0036	0.020	<0.001	0.04	3.48	0.52	0.34	<0.10
MEAN			0.0036	0.016	≤0.012	0.024	2.09	0.44	0.30	<0.10
STANDARD DEVIATION			0.0000	0.009	0.013	0.012	1.26	0.19	0.12	0.00
MGD			0.0288							
LBS/DAY				0.004	≤0.003	0.006	0.50	0.11	0.073	<0.024

TABLE D-35. POINT SOURCE 11, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-24-79	TH	6A	0.0050	0.008	0.020	0.01	0.68	0.56	0.40	<0.10
		8A	0.0050	0.016	0.066	0.02	1.07	0.55	0.47	<0.10
		10A	0.0050	0.013	0.074	0.07	0.96	0.56	0.58	0.37
		12P	0.0050	0.007	0.055	0.01	0.52	0.49	0.45	<1.10
		2P	0.0050	0.002	0.027	0.01	0.34	0.57	0.34	0.18
		4P	0.0050	0.005	0.012	0.01	0.60	0.58	0.39	0.14
		6P	0.0050	0.011	0.007	0.01	0.54	0.29	0.18	0.10
		8P	0.0050	0.010	0.006	0.01	0.49	0.43	0.20	<0.10
MEAN			0.0050	0.009	0.033	0.02	0.65	0.50	0.38	<0.29
STANDARD DEVIATION			0.0000	0.004	0.028	0.02	0.25	0.10	0.13	0.38
MGD			0.0397							
LBS/DAY				0.003	0.011	0.008	0.22	0.17	0.13	<0.095

TABLE D-36. POINT SOURCE 12, SAMPLING DAY ONE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN¯
2-19-79	M	6P	0.003	0.001	2.29	<0.01	0.06	0.064	3.96	<0. 10
		8P	0.003	<0.001	0.07	0.02	0.06	0.051	1.09	<0.10
		10P	0.015	<0.001	5.06	<0.01	0.05	0.060	2.73	<0.10
2-20-79	T	12A	0.015	<0.001	5.28	<0.01	0.03	0.074	1.32	<0.10
		2A	0.004	<0.001	1.71	<0.01	0.02	0.047	0.96	<0.10
		4A	0.004	<0.001	0.51	<0.01	0.02	0.051	0.77	<0.10
		6A	0.030	<0.001	0.23	<0.01	0.01	0.046	0.72	<0.10
		8A	0.030	<0.001	1.21	<0.01	0.06	0.055	1.71	<0.10
		10A	0.013	0.003	0.09	0.01	0.03	0.052	10.75	<0.10
		12P	0.013	<0.001	0.12	<0.01	0.01	0.047	0.97	<0.10
		2P	0.007	0.001	2.34	0.01	0.04	0.141	5.17	<0.10
		4P	0.007	<0.001	0.11	0.01	0.04	0.040	0.60	<0.10
MEAN			0.012	<0.002	1.59	<0.02	0.04	0.061	2.56	<0.10
STANDARD DEVIATION			0.010	0.001	1.88	0.01	0.02	0.027	2.95	0.00
MGD			0.114							
LBS/DAY				<0.00	1.95	<0.012	0.041	0.069	2.91	<0.12

TABLE D-37. POINT SOURCE 12, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
2-13-79	T	6P	0.011	0.007	2.46	0.01	0.13	0.150	44.42	<0.10
		8P	0.011	<0.001	0.83	<0.01	0.05	0.053	4.03	<0.10
		10P	0.015	<0.001	15.56	<0.01	0.09	0.035	6.43	<0.10
2-14-79	W	12A	0.015	<0.001	0.76	<0.01	0.01	0.018	1.95	<0.10
		2A	0.021	<0.001	1.42	<0.01	0.04	0.044	5.33	<0.10
		4A	0.021	<0.001	7.31	<0.01	0.04	0.044	3.63	<0.10
		6A	0.027	<0.001	1.62	<0.01	0.03	0.037	1.26	<0.10
		8A	0.027	<0.001	2.13	<0.01	0.08	0.044	0.87	<0.10
		10A	0.014	<0.001	6.26	<0.01	0.03	0.069	27.45	<0.10
		12P	0.014	<0.001	7.00	<0.01	0.05	0.044	6.73	<0.10
		2P	0.014	<0.001	5.49	<0.01	0.03	0.045	4.28	<0.10
		4P	0.014	<0.001	3.27	<0.01	0.03	0.051	2.45	<0.10
MEAN			0.017	<0.002	4.51	<0.01	0.05	0.053	9.07	<0.10
STANDARD DEVIATION			0.006	0.002	4.23	0.00	0.03	0.033	13.19	0.00
MGD			0.204							
LBS/DAY				<0.002	7.29	<0.017	0.084	0.083	12.32	<0.17

TABLE D-38. POINT SOURCE 12, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
2-14-79	W	6P	0.012	0.002	0.92	<0.01	0.07	0.041	3.21	<0.10
		8P	0.012	<0.001	0.88	<0.01	0.03	0.034	1.52	<0.10
		10P	0.010	<0.001	0.69	<0.01	0.03	0.027	2.37	<0.10
2-15-79	TH	12A	0.013	<0.001	13.48	<0.01	0.02	0.043	1.69	<0.10
		2A	0.013	<0.001	2.15	<0.01	0.01	0.034	0.78	<0.10
		4A	0.039	<0.001	0.16	<0.01	0.04	0.033	0.52	<0.10
		6A	0.039	<0.001	0.10	<0.01	0.01	0.030	0.54	<0.10
		8A	0.013	<0.001	0.11	<0.01	0.06	0.026	0.45	<0.10
		10A	0.013	0.001	0.41	0.02	0.10	0.078	112.53	<0.10
		12P	0.013	0.001	2.14	0.01	0.15	0.062	30.81	<0.10
		2P	0.014	<0.001	1.14	<0.01	0.10	0.043	14.96	<0.10
		4P	0.014	<0.001	25.23	<0.01	0.07	0.031	4.95	<0.10
MEAN			0.018	<0.002	3.95	<0.02	0.06	0.040	14.53	<0.10
STANDARD DEVIATION			0.010	0.001	7.65	0.01	0.04	0.015	32.12	0.00
MGD			0.205							
LBS/DAY				<0.002	5.38	<0.018	0.085	0.065	19.20	<0.18

APPENDIX E

TRUNKLINE MONITORING TABLES

TABLE E-1. CLASSIFICATION AND CODE OF SIX MAJOR TRUNKLINES TO THE KOKOMO POTW

Trunkline	Code	Classification
Dixon Road	T-1	Residential
Fayble	T-2	Residential
New Pete's Run	T-3	Residential, Commercial, and Industrial
Northside	T-4	Residential, Commercial, and Industrial
North West	T-6	Residential
Pete's Run	T-5	Residential, Commercial, and Industrial
North Northside Int.	T-4a	
Indiana Feeder	T-4a-1	
Washington Feeder	T-4a-2	
Apperson Feeder	T-4a-3	
South Northside Int.	T-4b	
Union Feeder	T-4b-1	
Old Park Road	T-5b	

TABLE E-2. DIXON ROAD INTERCEPTOR TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
4-24-78	M	6P	0.025	<0.001	0.007	<0.01	0.01	0.062	0.055	<0.10
		8P	0.028	<0.001	0.006	<0.01	0.01	0.053	0.060	<0.10
		10P	0.026	<0.001	0.011	0.01	0.01	0.080	0.080	<0.10
4-25-78	T	12A	0.024	<0.001	0.006	0.01	0.02	0.080	0.069	<0.10
		2A	0.029	<0.001	0.008	<0.01	0.03	0.132	0.043	<0.10
		4A	0.030	<0.001	0.022	0.01	0.06	0.251	0.076	<0.10
5-2-78		6A	0.020	<0.001	0.003	0.01	<0.01	0.032	0.020	<0.10
		8A	0.025	<0.001	0.001	0.01	<0.01	0.078	0.025	<0.10
		10A	0.029	<0.001	0.002	0.01	0.01	0.223	0.051	<0.10
		12P	0.050	<0.001	0.008	0.01	0.02	0.083	0.033	<0.10
		2P	0.048	<0.001	0.006	0.01	0.02	0.085	0.051	<0.10
		4P	0.046	<0.001	0.002	<0.01	<0.01	0.025	0.019	<0.10
MEAN			0.032	<0.001	0.007	<0.01	<0.02	0.098	0.049	<0.10
STANDARD DEVIATION			0.010	0.000	0.006	0.00	0.02	0.070	0.021	0.00
MGD			0.380							
LBS/DAY				<0.003	0.022	0.030	0.060	0.30	0.14	<0.30

TABLE E-3. DIXON ROAD INTERCEPTOR TRUNKLINE, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-11-78	T	6P	0.045	<0.001	0.001	<0.01	<0.01	0.090	0.012	<0.10
		8P	0.046	<0.001	0.003	0.01	<0.01	0.044	0.048	<0.10
		10P	0.043	<0.001	0.003	<0.01	<0.01	0.030	0.033	<0.10
4-12-78	W	12A	0.039	<0.001	0.004	<0.01	0.01	0.026	0.030	<0.10
		2A	0.036	<0.001	0.001	<0.01	0.01	0.044	0.010	<0.10
		4A	0.035	<0.001	0.003	<0.01	<0.01	0.023	0.008	<0.10
		6A	0.036	<0.001	0.001	<0.01	<0.01	0.017	0.008	<0.10
		8A	0.039	<0.001	0.001	<0.01	0.01	0.013	0.022	<0.10
		10A	0.040	<0.001	0.002	<0.01	0.01	0.015	0.035	<0.10
		12P	0.040	<0.001	0.003	<0.01	<0.01	0.091	0.057	<0.10
		2P	0.040	<0.001	0.002	<0.01	<0.01	0.038	0.034	<0.10
		4P	0.039	<0.001	0.003	0.01	0.01	0.058	0.069	<0.10
MEAN			0.040	<0.001	0.002	<0.01	<0.01	0.041	0.031	<0.10
STANDARD DEVIATION			0.003	0.000	0.001	0.00	0.00	0.027	0.020	0.00
MGD			0.478							
LBS/DAY				<0.004	0.008	<0.040	<0.040	0.16	0.11	<0.40

TABLE E-4. DIXON ROAD INTERCEPTOR TRUNKLINE, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-12-78	W	6P	0.039	<0.001	0.003	0.01	0.01	0.049	0.059	<0.10
		8P	0.039	<0.001	0.006	0.01	0.01	0.063	0.058	<0.10
		10P	0.037	<0.001	0.006	0.01	0.02	0.079	0.059	<0.10
4-13-78	TH	12A	0.033	<0.001	0.005	0.01	0.01	0.061	0.036	<0.10
		2A	0.031	<0.001	0.005	0.01	0.01	0.048	0.027	<0.10
		4A	0.030	<0.001	0.003	0.01	0.01	0.048	0.023	<0.10
		6A	0.030	<0.001	0.003	0.01	<0.01	0.034	0.016	<0.10
		8A	0.034	<0.001	0.002	0.01	<0.01	0.034	0.026	<0.10
		10A	0.034	<0.001	0.001	<0.01	<0.01	0.023	0.026	<0.10
		12P	0.033	<0.001	0.004	<0.01	<0.01	0.064	0.069	<0.10
		2P	0.033	<0.001	0.008	0.01	<0.01	0.025	0.021	<0.10
		4P	0.033	<0.001	0.005	0.01	0.01	0.053	0.066	<0.10
MEAN			0.034	<0.001	0.004	<0.01	<0.01	0.048	0.041	<0.10
STANDARD DEVIATION			0.003	0.000	0.002	0.00	0.00	0.017	0.020	0.00
MGD			0.406							
LBS/DAY				<0.003	0.014	<0.033	<0.037	0.16	0.14	<0.34

TABLE E-5. FAYBLE INTERCEPTOR TRUNKLINE, SAMPLING DAY ONE

				METAL AND CYANIDE CONCENTRATIONS (mg/l)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
1-22-79	M	6P	0.027	<0.001	0.020	0.01	<0.01	0.14	0.12	<0.10
		8P	0.027	<0.001	0.017	0.01	<0.01	0.14	0.12	<0.10
		10P	0.025	<0.001	0.010	<0.01	<0.01	0.14	0.14	<0.10
1-23-79	T	12A	0.019	<0.001	0.003	<0.01	0.01	0.27	0.10	<0.10
		2A	0.014	0.001	0.015	0.01	0.01	0.16	0.10	<0.10
		4A	0.011	0.001	<0.001	<0.01	0.01	0.13	0.10	<0.10
		6A	0.014	<0.001	<0.001	<0.01	0.01	0.08	0.08	<0.10
		8A	0.027	<0.001	<0.001	<0.01	<0.01	0.07	0.07	<0.10
		10A	0.028	<0.001	<0.001	<0.01	<0.01	0.12	0.12	<0.10
		12P	0.027	<0.001	0.009	0.01	<0.01	0.17	0.18	<0.10
		2P	0.027	<0.001	0.007	0.01	<0.01	0.16	0.14	<0.10
		4P	0.027	0.001	0.001	0.02	<0.01	0.34	0.31	<0.10
MEAN			0.023	<0.001	<0.010	<0.01	<0.01	0.16	0.13	<0.10
STANDARD DEVIATION			0.006	0.000	0.001	0.00	0.00	0.08	0.06	0.00
MGD			0.273							
LBS/DAY				<0.002	<0.017	<0.025	<0.023	0.40	0.31	<0.23

TABLE E-6. FAYBLE INTERCEPTOR TRUNKLINE, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/l)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-25-79	M	6P	0.059	0.001	0.017	0.01	0.03	0.05	0.23	<0.10
		8P	0.061	0.001	0.014	0.01	0.03	0.04	0.23	<0.10
		10P	0.057	0.001	0.008	0.01	0.02	0.04	0.19	<0.10
6-26-79	T	12A	0.055	0.002	0.013	<0.01	0.02	0.03	0.17	<0.10
		2A	0.043	0.001	0.010	0.01	0.02	0.04	0.18	<0.10
		4A	0.036	0.003	0.020	0.02	0.02	0.03	0.14	<0.10
		6A	0.034	0.003	0.017	0.01	0.04	0.03	0.14	<0.10
		8A	0.046	0.003	0.014	0.01	0.03	0.02	0.11	<0.10
		10A	0.066	0.004	0.015	0.01	0.03	0.03	0.14	<0.10
		12P	0.085	0.001	0.025	0.01	0.02	0.28	0.34	<0.10
		2P	0.062	<0.001	0.010	<0.01	0.04	0.17	0.25	<0.10
		4P	0.057	0.003	0.012	0.02	0.03	0.03	0.16	<0.10
MEAN			0.055	≤0.002	0.015	≤0.01	0.03	0.07	0.19	<0.10
STANDARD DEVIATION			0.014	0.001	0.005	0.00	0.01	0.08	0.06	0.00
MGD			0.661							
LBS/DAY				≤0.010	0.082	≤0.062	0.15	0.44	1.11	< 0.55

TABLE E-7. FAYBLE INTERCEPTOR TRUNKLINE, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
6-26-79	T	6P	0.063	0.005	0.214	0.09	0.11	5.26	0.62	<0.10
		8P	0.098	0.004	0.065	0.02	0.11	5.87	0.53	<0.10
		10P	0.085	0.003	0.039	0.02	0.07	4.18	0.40	0.23
6-27-79	W	12A	0.045	0.003	0.030	0.01	0.08	4.04	0.37	<0.10
		2A	0.041	0.003	0.016	0.01	0.03	0.39	0.16	<0.10
		4A	0.035	0.003	0.018	0.01	0.03	0.26	0.15	0.88
		6A	0.036	0.007	0.036	0.11	0.06	6.43	0.39	0.26
		8A	0.048	0.004	0.023	0.01	0.04	0.42	0.17	1.32
		10A	0.067	0.002	0.027	0.01	0.04	3.78	0.27	0.20
		12P	0.063	0.002	0.015	<0.01	0.04	1.08	0.16	0.11
		2P	0.079	0.001	0.013	0.01	0.03	0.24	0.17	<0.10
		4P	0.071	0.001	0.021	0.02	0.04	0.31	0.22	<0.10
	MEAN		0.061	0.003	0.043	$\le$0.03	0.06	2.69	0.30	<0.30
	STANDARD DEVIATION		0.020	0.002	0.056	0.04	0.03	2.46	0.16	0.39
	MGD		0.731							
	LBS/DAY			0.027	0.28	$\le$0.15	0.37	17.37	1.94	<1.53

TABLE E-8. FAYBLE INTERCEPTOR TRUNKLINE, SAMPLING DAY FOUR

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-27-79	W	6P	0.082	0.001	0.087	0.01	0.04	0.54	0.19	<0.10
		8P	0.107	0.001	0.017	0.01	0.04	0.62	0.22	<0.10
		10P	0.092	0.001	0.016	0.01	0.03	0.61	0.19	<0.10
6-28-79	TH	12A	0.067	0.001	0.014	0.01	0.02	0.31	0.13	<0.10
		2A	0.052	0.001	0.013	<0.01	0.02	0.29	0.15	<0.10
		4A	0.044	0.001	0.020	0.02	0.02	0.30	0.13	<0.10
		6A	0.046	<0.001	0.007	0.01	0.02	0.35	0.13	<0.10
		8A	0.060	0.001	0.006	0.01	0.02	0.29	0.10	<0.10
		10A	0.077	0.001	0.018	0.01	0.02	0.26	0.15	<0.10
		12P	0.076	0.001	0.013	0.01	0.02	0.38	0.16	<0.10
		2P	0.085	0.001	0.012	0.01	0.02	0.95	0.18	<0.10
		4P	0.079	0.001	0.006	0.01	0.02	0.27	0.15	<0.10
MEAN			0.072	≤0.001	0.019	≤0.01	0.02	0.43	0.16	<0.10
STANDARD DEVIATION			0.019	0.000	0.022	0.01	0.01	0.21	0.03	<0.10
MGD			0.867							
LBS/DAY				≤0.007	0.15	≤0.072	0.18	3.34	1.18	<0.72

TABLE E-9. NEW PETE'S RUN TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
9-25-78	M	6P	0.298	0.18	0.010	0.22	0.01	0.44	0.82	0.21
		8P	0.295	0.12	0.022	0.21	0.01	0.62	0.69	0.39
		10P	0.283	0.12	0.008	0.19	0.02	0.65	0.55	0.46
9-26-78	T	12A	0.253	0.19	0.004	0.18	0.01	0.48	0.69	0.67
		2A	0.231	0.13	0.004	0.16	0.01	0.33	0.60	0.49
		4A	0.238	0.13	0.009	0.19	0.02	0.42	0.78	0.52
		6A	0.246	0.12	0.008	0.17	0.01	0.36	0.58	0.42
		8A	0.291	0.09	0.006	0.14	0.01	0.33	0.53	0.37
		10A	0.257	0.14	0.006	0.14	0.01	0.77	0.73	0.29
		12P	0.160	0.21	0.008	0.05	0.03	0.94	0.35	<0.10
		2P	0.207	0.21	0.007	0.02	0.02	0.92	0.22	<0.10
		4P	0.298	0.11	0.007	0.13	0.01	0.68	0.69	0.23
MEAN			0.255	0.15	0.008	0.15	0.014	0.58	0.60	≤0.10
STANDARD DEVIATION			0.042	0.04	0.004	0.06	0.006	0.22	0.17	0.20
MGD			3.057							
LBS/DAY				3.62	0.22	3.99	0.33	14.47	15.82	≤8.91

TABLE E-10. NEW PETE'S RUN TRUNKLINE, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
9-26-78	T	6P	0.275	0.19	0.017	0.15	0.02	0.59	0.65	0.62
		8P	0.268	0.01	0.006	0.01	0.01	0.06	0.06	0.32
		10P	0.231	0.14	0.009	0.10	0.01	0.24	0.33	0.17
9-27-78	W	12A	0.224	0.11	0.008	0.12	0.02	0.54	0.41	0.25
		2A	0.148	0.12	0.007	0.15	0.01	0.23	0.45	0.56
		4A	0.093	0.06	0.004	0.07	0.02	0.33	0.29	0.10
		6A	0.104	0.01	0.007	0.04	0.02	0.30	0.07	<0.10
		8A	0.148	0.07	0.008	0.04	0.02	0.67	0.08	<0.10
		10A	0.246	0.10	0.053	0.01	0.01	0.58	0.24	0.10
		12P	0.302	0.18	0.278	0.34	0.02	0.38	0.51	0.11
		2P	0.298	0.32	0.022	0.30	0.02	0.67	0.87	0.17
		4P	0.291	0.18	0.007	0.14	0.01	0.23	0.49	0.13
MEAN			0.219	0.12	0.036	0.12	0.02	0.40	0.37	≤0.23
STANDARD DEVIATION			0.076	0.09	0.077	0.11	0.01	0.21	0.25	0.18
MGD			2.628							
LBS/DAY				3.12	0.99	3.07	0.30	8.96	9.11	≤4.92

TABLE E-11. NEW PETE'S RUN TRUNKLINE, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
9-27-78	W	6P	0.257	0.14	0.264	0.37	0.01	0.36	0.57	0.29
		8P	0.203	0.23	0.275	0.41	0.01	0.31	0.60	0.14
		10P	0.143	0.12	0.060	0.07	0.02	0.31	0.14	<0.10
9-28-78	Th	12A	0.130	0.26	0.031	0.09	0.03	0.71	0.18	<0.10
		2A	0.115	0.18	0.003	0.03	0.01	0.21	0.08	<0.10
		4A	0.101	0.03	0.002	0.03	0.01	0.14	0.09	<0.10
		6A	0.093	0.03	0.322	0.20	0.02	0.25	0.36	0.10
		8A	0.170	0.04	0.073	0.01	0.02	0.30	0.43	0.13
		10A	0.221	0.14	0.233	0.27	0.01	0.39	0.60	0.69
		12P	0.268	0.12	0.233	0.23	0.01	0.36	0.59	0.24
		2P	0.298	0.11	0.015	0.14	0.01	0.32	0.53	0.10
		4P	0.287	0.18	0.006	0.15	0.01	0129	0.70	0.11
MEAN			0.191	0.13	0.13	0.17	0.015	0.33	0.41	<0.18
STANDARD DEVIATION			0.075	0.07	0.13	0.13	0.007	0.14	0.23	0.17
MGD			2.286							
LBS/DAY				2.62	2.52	3.61	0.26	6.38	9.06	<3.85

TABLE E-12. NORTH NORTHSIDE INTERCEPTOR TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
6-12-78	M	6P	0.350	0.22	1.07	0.17	0.02	1.96	0.10	<0.10
		8P	0.334	0.12	1.15	0.14	0.04	2.96	0.09	<0.10
		10P	0.323	0.15	1.09	0.20	0.04	0.79	0.09	0.18
6-13-78	T	12A	0.311	0.20	1.53	0.24	0.02	0.74	0.12	0.10
		2A	0.291	0.14	0.77	0.06	0.01	0.66	0.08	<0.10
		4A	0.271	0.18	1.70	0.17	0.01	0.72	0.08	<0.10
		6A	0.258	0.22	1.54	0.08	0.01	0.82	0.08	<0.10
		8A	0.265	0.23	0.49	0.07	0.01	1.34	0.08	0.10
		10A	0.312	0.16	0.69	0.08	0.01	1.79	0.13	<0.10
		12P	0.347	0.16	1.06	0.38	0.01	3.42	0.12	<0.10
		2P	0.353	0.07	1.00	0.20	0.03	2.60	0.10	<0.10
		4P	0.344	0.09	0.80	0.23	0.03	3.17	0.11	<0.10
MEAN			0.313	0.16	1.07	0.17	0.02	1.75	0.10	<0.11
STANDARD DEVIATION			0.035	0.05	0.37	0.09	0.01	1.06	0.02	0.02
MGD			3.760							
LBS/DAY				4.97	33.44	5.48	0.65	57.27	3.14	<3.35

TABLE E-13. NORTH NORTHSIDE INTERCEPTOR TRUNKLINE, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-6-78	T	6P	0.340	0.13	1.14	0.14	0.04	1.22	0.11	<0.10
		8P	0.338	0.07	1.05	0.17	0.06	1.64	0.10	0.10
		10P	0.338	0.07	0.77	0.15	0.02	1.46	0.08	0.10
6-7-78	W	12A	0.315	0.05	0.78	0.15	0.02	1.44	0.08	0.10
		2A	0.290	0.06	1.06	0.12	0.02	1.49	0.10	0.10
		4A	0.664	0.48	1.56	0.18	0.30	3.91	0.48	0.22
		6A	0.803	0.14	0.63	0.05	0.11	1.29	0.11	<0.10
		8A	0.803	0.03	1.11	0.04	0.09	0.60	0.09	<0.10
		10A	0.775	0.01	0.87	0.08	0.07	1.10	0.08	<0.10
		12P	0.614	0.02	1.17	0.08	0.05	0.92	0.07	<0.10
		2P	0.473	0.04	0.81	0.14	0.06	1.76	0.13	0.10
		4P	0.426	0.01	0.77	0.13	0.05	1.27	0.07	0.10
MEAN			0.515	0.09	0.98	0.12	0.07	1.51	0.13	<0.11
STANDARD DEVIATION			0.204	0.13	0.26	0.05	0.08	0.82	0.11	0.03
MGD			6.179							
LBS/DAY				5.21	51.22	5.52	4.57	77.16	6.91	<5.82

TABLE E-14. NORTH NORTHSIDE INTERCEPTOR TRUNKLINE, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-7-78	W	6P	0.375	0.04	0.68	0.13	0.05	1.20	0.09	<0.10
		8P	0.388	0.06	1.33	0.16	0.05	1.15	0.08	0.10
		10P	0.369	0.07	1.54	0.09	0.02	1.21	0.07	0.10
6-8-78	TH	12A	0.351	0.12	0.61	0.07	0.01	1.06	0.07	0.10
		2A	0.331	0.04	0.88	0.13	0.01	1.66	0.08	0.10
		4A	0.283	0.03	0.60	0.07	<0.01	1.32	0.06	<0.10
		6A	0.298	0.09	1.30	0.05	<0.01	1.03	0.06	<0.10
		8A	0.313	0.09	0.62	0.10	<0.01	1.64	0.06	<0.10
		10A	0.352	0.08	0.99	0.08	0.01	1.72	0.07	<0.10
		12P	0.366	0.09	0.78	0.15	0.04	1.31	0.10	<0.10
		2P	0.293	0.03	0.47	0.11	0.02	1.58	0.08	0.10
		4P	0.274	0.02	0.84	0.15	0.03	1.61	0.08	<0.10
MEAN			0.333	0.06	0.89	0.11	≤0.02	1.37	0.08	<0.10
STANDARD DEVIATION			0.039	0.03	0.34	0.04	0.02	0.25	0.01	0.00
MGD			3.993							
LBS/DAY				2.15	30.00	3.62	≤0.78	45.42	2.52	<3.33

TABLE E-15. NORTHWEST INTERCEPTOR TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
5-1-78	M	6P	0.015	0.001	0.002	<0.01	0.02	0.090	0.076	<0.10
		8P	0.014	0.001	0.002	<0.01	0.01	0.121	0.075	<0.10
		10P	0.014	<0.001	0.003	<0.01	0.02	0.096	0.097	<0.10
5-2-78	T	12A	0.011	<0.001	0.002	<0.01	0.01	0.071	0.072	<0.10
		2A	0.009	<0.001	<0.001	<0.01	0.02	0.055	0.052	<0.10
		4A	0.009	<0.001	<0.001	<0.01	0.01	0.049	0.069	<0.10
		6A	0.010	<0.001	<0.001	<0.01	<0.01	0.036	0.019	<0.10
		8A	0.014	<0.001	<0.001	<0.01	<0.01	0.085	0.100	<0.10
		10A	0.014	<0.001	0.003	<0.01	0.01	0.076	0.011	<0.10
		12P	0.013	0.001	0.001	<0.01	0.02	0.081	0.091	<0.10
		2P	0.012	0.004	0.004	<0.01	0.01	0.102	0.073	<0.10
		4P	0.013	0.001	0.001	0.01	0.01	0.064	0.070	<0.10
MEAN			0.012	<0.001	≤0.002	<0.01	<0.02	0.077	0.067	<0.10
STANDARD DEVIATION			0.002	0.001	0.001	0.00	0.01	0.024	0.029	0.00
MGD			0.148							
LBS/DAY				<0.002	≤0.002	<0.012	<0.017	0.095	0.079	<0.12

TABLE E-16. NORTHWEST INTERCEPTOR TRUNKLINE, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
4-11-78	T	6P	0.010	0.002	0.001	0.01	<0.01	0.090	0.012	<0.10
		8P	0.008	<0.001	0.002	<0.01	0.01	0.066	0.010	<0.10
		10P	0.008	<0.001	0.001	<0.01	<0.01	0.073	0.007	<0.10
4-12-78	W	12A	0.008	<0.001	<0.001	<0.01	<0.01	0.053	0.006	<0.10
		2A	0.008	0.001	0.002	<0.01	0.02	0.068	0.005	<0.10
		4A	0.007	<0.001	<0.001	<0.01	<0.01	0.059	0.004	<0.10
		6A	0.007	<0.001	<0.001	<0.01	0.02	0.061	0.005	<0.10
		8A	0.006	<0.001	<0.001	<0.01	<0.01	0.044	0.003	<0.10
		10A	0.006	<0.001	<0.001	<0.01	<0.01	0.059	0.011	<0.10
		12P	0.006	<0.001	0.001	<0.01	<0.01	0.055	0.013	<0.10
		2P	0.006	<0.001	<0.001	<0.01	0.01	0.037	0.009	<0.10
		4P	0.006	<0.001	0.001	<0.01	0.01	0.054	0.014	<0.10
MEAN			0.007	<0.002	<0.002	<0.01	<0.02	0.061	0.008	<0.10
STANDARD DEVIATION			0.001	0.001	0.001	0.00	0.01	0.014	0.004	0.00
MGD			0.086							
LBS/DAY				<0.001	<0.001	<0.007	<0.008	0.041	0.006	<0.071

TABLE E-17. NORTHWEST INTERCEPTOR TRUNKLINE, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
4-12-78	W	6P	0.006	<0.001	0.001	<0.01	0.01	0.037	0.009	<0.10
		8P	0.006	<0.001	0.001	<0.01	0.01	0.040	0.009	<0.10
		10P	0.005	0.001	0.001	0.01	0.01	0.044	0.005	<0.10
4-13-78	TH	12A	0.005	<0.001	0.001	<0.01	0.01	0.034	0.006	<0.10
		2A	0.005	<0.001	0.001	<0.01	<0.01	0.035	0.003	<0.10
		4A	0.005	<0.001	0.001	0.01	<0.01	0.039	0.005	<0.10
		6A	0.005	<0.001	0.001	<0.01	<0.01	0.033	0.004	<0.10
		8A	0.005	<0.001	0.001	<0.01	0.01	0.034	0.002	<0.10
		10A	0.005	<0.001	<0.001	<0.01	0.01	0.025	0.007	<0.10
		12P	0.005	<0.001	0.001	<0.01	0.01	0.034	0.010	<0.10
		2P	0.004	<0.001	0.001	<0.01	0.01	0.036	0.016	<0.10
		4P	0.005	<0.001	0.001	<0.01	0.01	0.038	0.016	<0.10
MEAN			0.005	<0.001	≤0.001	<0.01	<0.01	0.036	0.008	<0.10
STANDARD DEVIATION			0.001	0.000	0.000	0.00	0.00	0.005	0.005	0.00
MGD			0.061							
LBS/DAY				<0.001	≤0.001	<0.005	<0.005	0.018	0.004	<0.050

TABLE E-18. SOUTH NORTHSIDE INTERCEPTOR TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-5-78	M	6P	0.074	0.001	0.370	0.02	0.11	0.26	0.10	<0.10
		8P	0.075	0.001	0.053	0.01	0.02	0.33	0.10	<0.10
		10P	0.072	<0.001	0.084	0.02	0.01	0.30	0.11	<0.10
6-6-78	T	12A	0.066	<0.001	0.036	0.01	0.01	0.25	0.09	<0.10
		2A	0.058	<0.001	0.016	0.01	<0.01	0.23	0.08	<0.10
		4A	0.056	<0.001	0.012	<0.01	<0.01	0.23	0.05	<0.10
		6A	0.059	<0.001	0.020	<0.01	0.01	0.48	0.17	<0.10
		8A	0.079	0.001	0.020	<0.01	<0.01	0.28	0.07	<0.10
		10A	0.076	0.001	0.009	<0.01	0.01	0.34	0.98	<0.10
		12P	0.082	<0.001	0.007	<0.01	<0.01	0.49	0.09	<0.10
		2P	0.083	0.003	0.011	<0.01	0.01	0.23	0.10	<0.10
		4P	0.074	0.001	0.048	0.02	0.01	0.35	1.61	<0.10
MEAN			0.071	<0.002	0.057	<0.02	≤0.02	0.31	0.30	<0.10
STANDARD DEVIATION			0.009	0.001	0.101	0.01	0.03	0.09	0.49	0.00
MGD			0.854							
LBS/DAY				<0.008	0.41	0.090	≤0.14	2.27	1.61	<0.71

TABLE E-19. SOUTH NORTHSIDE INTERCEPTOR TRUNKLINE, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
6-13-78	T	6P	0.076	<0.001	0.040	0.02	0.01	1.31	0.10	<0.10
		8P	0.076	<0.001	0.008	<0.01	0.01	1.84	0.07	<0.10
		10P	0.072	<0.001	0.019	<0.01	0.01	1.59	0.07	<0.10
6-14-78	W	12A	0.064	<0.001	0.035	0.02	0.01	1.50	0.10	<0.10
		2A	0.062	<0.001	0.011	0.01	0.01	1.67	0.06	<0.10
		4A	0.064	<0.001	0.023	0.02	0.01	1.58	0.05	<0.10
		6A	0.072	<0.001	0.016	<0.01	0.01	1.85	0.05	<0.10
		8A	0.087	<0.001	0.012	<0.01	0.01	2.20	0.07	<0.10
		10A	0.088	<0.001	0.040	<0.01	0.01	1.58	0.07	<0.10
		12P	0.088	<0.001	0.016	0.02	0.01	1.49	0.36	<0.10
		2P	0.075	<0.001	0.024	0.02	0.01	2.02	0.48	<0.10
6-7-78		4P	0.079	0.001	0.035	0.02	0.02	0.35	0.09	<0.10
MEAN			0.075	<0.001	0.023	<0.02	0.01	1.58	0.13	<0.10
STANDARD DEVIATION			0.009	0.000	0.012	0.01	0.00	0.46	0.14	0.00
MGD			0.903							
LBS/DAY				<0.008	0.16	<0.11	0.069	11.90	1.01	<0.75

TABLE E-20. SOUTH NORTHSIDE INTERCEPTOR TRUNKLINE, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-7-78	W	6P	0.079	0.003	0.021	0.01	0.02	0.31	0.09	<0.10
		8P	0.077	0.002	0.017	0.01	0.01	0.19	0.08	<0.10
		10P	0.074	0.002	0.016	<0.01	0.02	0.18	0.08	<0.10
6-8-78	TH	12A	0.068	0.001	0.011	<0.01	0.01	0.14	0.06	<0.10
		2A	0.062	0.002	0.012	<0.01	0.01	0.19	0.06	<0.10
		4A	0.059	0.001	0.018	<0.01	0.01	0.31	0.09	<0.10
		6A	0.060	0.002	0.017	<0.01	0.01	0.40	0.08	<0.10
		8A	0.070	0.001	0.024	0.01	0.01	0.37	0.06	<0.10
		10A	0.070	0.001	0.019	0.01	0.01	0.37	0.07	<0.10
		12P	0.041	0.001	0.013	0.01	0.01	0.43	0.07	<0.10
		2P	0.093	0.001	0.035	0.01	0.03	0.52	0.20	<0.10
		4P	0.076	0.001	0.036	0.02	0.01	0.66	0.07	<0.10
MEAN			0.069	0.002	0.02	<0.02	0.02	0.34	0.08	<0.10
STANDARD DEVIATION			0.013	0.001	0.01	0.01	0.03	0.15	0.04	0.00
MGD			0.829							
LBS/DAY				0.011	0.14	<0.075	0.086	2.37	0.61	<0.69

TABLE E-21. APPERSONWAY FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-17-78	M	6P	0.081	0.003	0.003	0.19	0.02	0.56	0.052	<0.10
		8P	0.080	0.003	0.017	0.07	0.01	0.13	0.055	<0.10
		10P	0.078	0.001	0.004	0.02	<0.01	0.12	0.040	<0.10
7-18-78	T	12A	0.075	0.001	0.004	0.03	<0.01	0.09	0.036	<0.10
		2A	0.069	0.001	0.003	0.02	<0.01	0.14	0.029	<0.10
		4A	0.061	0.003	0.007	0.02	0.01	0.09	0.016	<0.10
		6A	0.059	0.002	0.008	0.01	<0.01	0.04	0.005	<0.10
		8A	0.061	0.002	0.004	0.03	<0.01	0.05	0.009	<0.10
		10A	0.067	0.003	<0.001	0.25	<0.01	0.43	0.015	<0.10
		12P	0.074	0.006	0.006	0.17	0.02	0.43	0.030	<0.10
		2P	0.079	0.003	0.003	0.18	0.06	0.71	0.054	<0.10
		4P	0.080	0.002	0.011	0.26	0.03	1.06	0.090	<0.10
MEAN			0.072	0.003	<0.003	0.10	<0.02	0.32	0.040	<0.10
STANDARD DEVIATION			0.008	0.001	0.002	0.10	0.02	0.32	0.024	0.00
MGD			0.864							
LBS/DAY				0.018	≤0.042	0.78	<0.13	2.45	0.27	<0.72

TABLE E-22. APPERSONWAY FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
7-19-78	W	6P	0.081	0.004	0.008	0.21	0.03	0.39	0.058	< 0.10
		8P	0.080	0.002	0.007	0.06	0.02	0.13	0.042	<0.10
		10P	0.076	0.002	0.004	0.01	0.01	0.14	0.028	<0.10
7-20-78	TH	12A	0.071	0.002	0.006	0.03	0.01	0.12	0.036	<0.10
		2A	0.063	0.001	0.010	0.02	0.01	0.04	0.023	<0.10
		4A	0.055	0.001	0.010	0.02	0.01	0.80	0.015	<0.10
		6A	0.052	0.003	0.010	0.02	0.01	0.09	0.021	<0.10
		8A	0.060	0.002	0.007	0.01	<0.01	0.06	0.007	<0.10
		10A	0.067	0.043	1.170	0.12	<0.01	0.93	0.401	<0.10
		12P	0.079	0.003	0.012	0.14	0.02	0.38	0.053	< 0.10
		2P	0.086	0.001	0.010	0.11	0.03	1.18	0.037	< 0.10
		4P	0.082	0.002	0.011	0.34	0.02	1.17	0.088	< 0.10
MEAN			0.071	0.006	0.105	0.09	≤0.02	0.45	0.066	< 0.10
STANDARD DEVIATION			0.011	0.012	0.335	0.10	0.01	0.44	0.110	0.00
MGD			0.852							
LBS/DAY				0.036	0.70	0.50	≤0.12	2.67	0.42	<0.71

TABLE E-23. APPERSONWAY FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY THREE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-24-78	M	6P	0.074	0.005	0.016	0.09	0.02	21.52	0.038	<0.10
		8P	0.070	0.013	0.016	0.05	0.02	44.52	0.051	<0.10
		10P	0.070	<0.001	0.006	0.02	0.01	0.26	0.061	<0.10
7-25-78	T	12A	0.063	0.031	0.009	0.03	0.06	114.86	0.027	<0.10
		2A	0.055	<0.001	0.008	0.01	0.01	0.22	0.017	<0.10
		4A	0.053	0.002	0.005	0.01	0.01	20.25	0.018	<0.10
		6A	0.056	<0.001	0.008	0.01	<0.01	0.16	0.016	<0.10
		8A	0.063	<0.001	0.003	0.01	<0.01	0.14	0.017	<0.10
		10A	0.072	0.001	0.005	0.13	<0.01	0.13	0.015	<0.10
		12P	0.077	<0.001	0.008	0.16	<0.01	0.32	0.027	<0.10
		2P	0.076	<0.001	0.010	0.20	<0.01	0.87	0.028	<0.10
		4P	0.074	0.001	0.021	0.35	0.02	0.70	0.081	<0.10
MEAN			0.067	<0.009	0.010	0.09	<0.02	16.99	0.033	<0.10
STANDARD DEVIATION			0.009	0.009	0.005	0.11	0.02	33.82	0.021	0.00
MGD			0.803							
LBS/DAY				<0.032	0.15	0.65	<0.11	110.24	0.23	<0.67

TABLE E-24. INDIANA STREET FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY ONE

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
7-24-78	M	6P	0.021	0.019	0.245	0.01	0.01	2.01	0.055	<0.10
		8P	0.020	0.002	0.281	0.02	0.01	7.35	0.062	<0.10
		10P	0.019	0.005	0.002	0.01	<0.01	14.83	0.050	<0.10
7-25-78	T	12A	0.016	0.002	<0.001	<0.01	0.01	0.23	0.056	<0.10
		2A	0.012	<0.001	0.002	<0.01	<0.01	0.86	0.038	<0.10
		4A	0.011	<0.001	<0.001	<0.01	<0.01	0.15	0.044	<0.10
		6A	0.012	0.004	<0.001	<0.01	<0.01	12.69	0.018	<0.10
		8A	0.017	0.002	0.002	<0.01	<0.01	0.11	0.033	<0.10
		10A	0.020	0.001	0.002	<0.01	<0.01	0.13	0.039	<0.10
		12P	0.020	0.001	<0.001	<0.01	<0.01	0.22	0.050	<0.10
		2P	0.020	0.003	<0.001	<0.01	0.01	0.13	0.047	<0.10
		4P	0.020	<0.001	0.002	<0.01	<0.01	0.14	0.046	<0.10
MEAN			0.017	≤0.004	≤0.045	<0.02	<0.01	3.24	0.045	<0.10
STANDARD DEVIATION			0.004	0.006	0.102	0.01	0.00	5.34	0.012	0.00
MGD			0.208							
LBS/DAY				≤0.006	≤0.091	<0.019	<0.017	5.37	0.070	<0.17

TABLE E-25. INDIANA STREET FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
7-26-78	W	6P	0.020	<0.001	<0.001	<0.01	0.01	0.09	0.042	<0.10
		8P	0.020	0.002	0.010	0.02	0.12	1.52	0.099	<0.10
		10P	0.021	<0.001	0.010	0.01	<0.01	0.09	0.015	<0.10
7-27-78	Th	12A	0.018	0.002	0.005	<0.01	0.02	0.12	0.040	<0.10
		2A	0.013	0.001	<0.001	<0.01	<0.01	0.09	0.024	<0.10
		4A	0.011	<0.001	0.001	<0.01	<0.01	0.05	0.020	<0.10
		6A	0.014	0.001	0.001	<0.01	<0.01	0.06	0.014	<0.10
		8A	0.019	0.001	0.004	<0.01	<0.01	0.05	0.031	<0.10
		10A	0.021	<0.001	<0.001	<0.01	<0.01	0.12	0.043	<0.10
		12P	0.022	<0.001	0.001	<0.01	<0.01	0.08	0.056	<0.10
		2P	0.021	<0.001	<0.001	<0.01	<0.01	0.07	0.060	<0.10
		4P	0.020	<0.001	<0.001	0.01	<0.01	0.13	0.058	<0.10
MEAN			0.018	<0.002	≤0.003	<0.02	<0.02	0.21	0.042	<0.10
STANDARD DEVIATION			0.004	0.001	0.004	0.01	0.03	0.41	0.024	0.00
MGD			0.220							
LBS/DAY				<0.002	≤0.006	<0.019	<0.040	0.40	0.081	<0.18

TABLE E-26. INDIANA STREET FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
8-1-78	T	6P	0.019	0.001	0.001	<0.01	<0.01	0.79	0.044	<0.10
		8P	0.017	0.001	0.001	0.03	<0.01	0.81	0.051	<0.10
		10P	0.017	<0.001	<0.001	<0.01	<0.01	0.87	0.061	<0.10
8-2-78	W	12A	0.013	<0.001	0.001	0.01	<0.01	0.85	0.052	<0.10
		2A	0.009	<0.001	0.051	0.03	<0.01	0.58	0.035	<0.10
		4A	0.008	<0.001	0.068	0.04	<0.01	0.44	0.118	<0.10
		6A	0.013	<0.001	0.220	0.12	0.01	0.98	5.772	<0.10
		8A	0.050	<0.001	0.056	0.04	0.03	1.93	11.980	<0.10
		10A	0.069	<0.001	0.057	0.03	0.04	1.46	10.002	<0.10
		12P	0.055	<0.001	0.063	0.04	0.01	0.89	0.025	<0.10
		2P	0.023	<0.001	0.076	0.04	0.01	1.01	36.999	<0.10
		4P	0.021	0.001	0.023	0.03	0.01	1.12	0.049	<0.10
MEAN			0.026	<0.001	0.056	≤0.04	<0.02	0.98	5.441	<0.10
STANDARD DEVIATION			0.020	0.000	0.061	0.03	0.01	0.40	10.832	0.00
MGD			0.314							
LBS/DAY				<0.002	≤0.13	<0.091	<0.052	3.38	18.53	<0.26

TABLE E-27. WASHINGTON STREET FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-26-78	M	6P	0.143	0.10	3.05	0.17	0.02	3.54	0.45	0.72
		8P	0.133	0.18	1.68	0.21	0.02	2.41	0.34	0.10
		10P	0.130	0.06	1.67	0.14	0.01	2.49	0.30	<0.10
6-27-78	T	12A	0.123	0.07	2.23	0.17	0.01	2.75	0.31	0.10
		2A	0.112	0.05	2.83	0.15	0.01	2.80	0.22	0.10
		4A	0.108	0.05	1.63	0.13	0.01	2.22	0.28	<0.10
		6A	0.109	0.05	1.96	0.05	<0.01	2.15	0.13	0.10
		8A	0.119	0.04	4.10	0.07	0.01	2.87	0.20	<0.10
		10A	0.140	0.38	4.68	0.24	0.01	1.78	0.16	0.10
		12P	0.146	0.38	4.69	0.15	0.02	1.78	0.21	0.15
		2P	0.145	0.44	1.88	0.11	0.07	48.34	0.20	0.52
		4P	0.145	0.14	2.35	0.09	0.01	2.79	0.15	0.11
MEAN			0.129	0.16	2.73	0.14	≤0.02	6.33	0.25	<0.19
STANDARD DEVIATION			0.015	0.15	1.16	0.06	0.02	13.34	0.09	0.21
MGD			1.553							
LBS./DAY				2.25	35.89	1.83	≤0.2	87.91	3.23	<2.62

TABLE E-28. WASHINGTON STREET FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-27-78	T	6P	0.138	0.09	5.93	0.27	0.02	1.92	0.23	<0.10
		8P	0.130	0.04	5.58	0.18	0.02	9.44	0.44	0.10
		10P	0.127	0.03	5.40	0.18	0.01	2.02	0.16	0.10
6-28-78	W	12A	0.120	0.03	5.83	0.16	0.02	2.01	0.18	0.10
		2A	0.112	0.03	2.38	0.20	0.02	2.38	0.22	0.12
		4A	0.106	0.02	1.76	0.14	0.01	1.86	0.18	0.14
		6A	0.107	0.02	1.03	0.14	0.01	2.80	0.16	0.10
		8A	0.118	0.05	0.84	0.14	0.01	1.07	0.20	0.10
		10A	0.140	0.30	3.97	0.20	0.01	1.70	0.13	0.10
		12P	0.148	0.48	2.20	0.26	0.02	1.16	0.24	0.10
		2P	0.183	0.10	0.58	0.22	0.01	0.95	0.14	0.10
		4P	0.146	0.11	0.47	0.24	0.02	0.75	0.15	<0.10
MEAN			0.131	0.11	3.00	0.19	0.02	2.34	0.20	<0.11
STANDARD DEVIATION			0.022	0.14	2.20	0.05	0.01	2.32	0.08	0.01
MGD			1.575							
LBS/DAY				1.54	38.85	2.61	0.19	30.74	2.64	<1.37

TABLE E-29. WASHINGTON STREET FEEDER LINE TO THE NORTH NORTHSIDE INTERCEPTOR, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-28-78	W	6P	0.143	0.11	2.55	0.44	0.02	3.40	0.27	0.10
6-21-78		8P	0.138	0.35	4.21	1.03	0.02	7.38	3.71	0.44
		10P	0.134	0.10	5.31	0.21	0.01	3.35	0.54	9.33
6-29-78	TH	12A	0.128	0.01	1.36	0.13	0.01	1.40	0.10	0.49
		2A	0.122	0.14	1.59	0.19	0.02	2.53	0.59	0.69
		4A	0.113	0.47	3.54	0.11	0.01	3.24	3.84	1.39
		6A	0.111	0.20	1.65	0.07	0.03	2.66	0.18	0.21
		8A	0.125	0.38	0.81	0.07	0.02	2.13	0.18	0.32
		10A	0.157	0.12	1.24	0.75	0.03	2.06	0.16	0.51
		12P	0.159	0.36	1.51	0.28	0.03	2.16	0.25	0.46
		2P	0.163	0.10	0.85	0.17	0.05	2.08	0.28	0.41
		4P	0.153	0.06	0.66	0.19	0.03	1.70	1.77	0.18
MEAN			0.137	0.20	2.11	0.30	0.02	2.84	0.99	1.21
STANDARD DEVIATION			0.018	0.15	1.49	0.30	0.01	1.57	1.38	2.58
MGD			1.648							
LBS/DAY				2.68	28.22	4.32	0.33	38.66	13.05	16.18

TABLE E-30. UNION STREET FEEDER LINE TO THE SOUTH NORTHSIDE INTERCEPTOR, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
8-14-78	M	6P	0.050	<0.001	0.187	0.02	0.02	3.75	0.39	<0.10
		8P	0.049	<0.001	0.083	0.04	<0.01	2.13	0.20	<0.10
		10P	0.048	0.001	0.147	0.04	0.01	2.08	1.04	<0.10
8-15-78	T	12A	0.044	<0.001	0.160	0.03	0.01	1.53	0.84	<0.10
		2A	0.044	<0.001	0.148	0.04	<0.01	1.54	0.17	<0.10
		4A	0.046	<0.001	0.065	0.03	<0.01	0.88	0.25	<0.10
		6A	0.050	<0.001	0.136	0.04	0.03	2.71	0.26	<0.10
		8A	0.053	<0.001	0.084	0.04	<0.01	1.88	0.26	<0.10
		10A	0.055	<0.001	0.173	0.05	0.01	2.11	0.52	<0.10
		12P	0.048	0.001	0.157	0.04	0.03	3.22	0.27	<0.10
		2P	0.047	<0.001	0.130	0.06	0.02	2.70	0.29	<0.10
8-22-78		4P	0.042	<0.001	0.141	0.06	0.02	3.74	0.15	<0.10
MEAN			0.048	<0.001	0.134	0.04	<0.02	2.36	0.397	<0.10
STANDARD DEVIATION			0.004	0.000	0.038	0.01	0.01	0.89	0.290	0.00
MGD			0.576							
LBS/DAY				<0.005	0.65	0.20	<0.071	11.32	1.86	<0.48

TABLE E-31. UNION STREET FEEDER LINE TO THE SOUTH NORTHSIDE INTERCEPTOR, SAMPLING DAY TWO

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
8-22-78	T	6P	0.040	<0.001	0.041	<0.01	0.01	1.57	1.251	<0.10
		8P	0.039	<0.001	0.087	0.05	0.02	3.86	1.25	<0.10
		10P	0.040	0.001	0.209	0.05	0.02	3.59	0.65	<0.10
8-23-78	W	12A	0.038	0.001	0.127	0.05	0.03	0.61	0.60	<0.10
		2A	0.037	<0.001	0.143	0.01	0.03	1.21	0.27	<0.10
		4A	0.039	<0.001	0.102	0.04	0.02	0.97	0.34	<0.10
		6A	0.043	<0.001	0.166	0.06	0.02	1.63	0.28	<0.10
		8A	0.041	<0.001	0.137	0.04	0.01	1.45	0.29	<0.10
		10A	0.043	<0.001	0.093	0.05	0.01	2.04	0.43	<0.10
		12P	0.044	<0.001	0.108	0.05	0.02	1.42	0.38	<0.10
		2P	0.040	0.002	0.128	0.04	0.02	1.68	0.55	<0.10
		4P	0.044	<0.001	0.124	0.04	0.02	2.02	0.25	<0.10
MEAN			0.041	<0.002	0.122	≤0.05	0.02	1.84	0.55	<0.10
STANDARD DEVIATION			0.002	0.001	0.042	0.16	0.01	0.97	0.36	0.00
MGD			0.488							
LBS/DAY				<0.004	0.50	≤0.16	0.077	7.49	2.19	<0.41

TABLE E-32. UNION STREET FEEDER LINE TO THE SOUTH NORTHSIDE INTERCEPTOR, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
8-23-78	W	6P	0.045	<0.001	0.138	0.07	0.01	0.22	0.55	<0.10
		8P	0.040	<0.001	0.132	0.06	0.03	0.24	0.26	<0.10
		10P	0.043	<0.001	0.279	0.06	0.03	0.19	0.33	<0.10
		12A	0.038	<0.001	0.143	0.06	0.02	0.20	0.35	<0.10
8-17-78	Th	2A	0.035	<0.001	0.082	0.04	0.02	0.19	0.40	<0.10
		4A	0.032	<0.001	0.044	0.01	0.03	0.19	0.14	<0.10
		6A	0.033	0.001	0.174	0.01	0.02	0.24	0.18	<0.10
		8A	0.037	<0.001	0.112	0.03	0.03	0.27	0.27	<0.10
		10A	0.040	<0.001	0.139	0.01	0.04	0.25	0.64	<0.10
		12P	0.043	0.001	0.156	0.01	0.04	0.22	0.78	<0.10
		2P	0.044	<0.001	0.148	0.03	0.03	0.25	0.58	<0.10
		4P	0.043	0.001	0.107	0.03	0.01	0.29	0.35	<0.10
MEAN			0.039	<0.001	0.143	0.03	0.03	0.23	0.40	<0.10
STANDARD DEVIATION			0.004	0.000	0.056	0.02	0.01	0.03	0.20	0.00
MGD			0.473							
LBS/DAY				<0.004	0.55	0.14	0.10	0.91	1.64	<0.39

TABLE E-33. OLD PARK ROAD TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
11-20-78	M	6P	0.075	0.002	0.002	6.25	0.02	0.26	0.13	0.15
		8P	0.077	0.002	0.048	6.75	0.01	0.16	0.07	0.10
		10P	0.075	0.004	0.130	4.42	0.01	0.23	0.14	<0.10
11-21-78	T	12A	0.062	0.003	0.050	4.30	0.01	0.15	0.09	0.16
		2A	0.052	0.003	0.093	5.95	<0.01	0.13	0.07	0.16
		4A	0.047	0.003	0.068	9.57	<0.01	0.13	0.06	0.10
		6A	0.047	<0.001	0.017	9.94	<0.01	0.09	0.03	<0.10
		8A	0.071	0.001	0.075	10.08	0.01	0.21	0.12	0.10
		10A	0.071	0.002	0.061	7.90	0.01	0.18	0.11	0.10
		12P	0.076	0.076	0.711	8.98	0.01	0.20	0.10	0.10
		2P	0.073	0.002	0.828	7.39	0.01	0.23	0.11	0.12
		4P	0.064	0.001	0.068	6.46	0.01	0.21	0.09	0.12
MEAN			0.066	≤0.00	0.18	7.33	<0.02	0.18	0.09	≤0.12
STANDARD DEVIATION			0.011	0.021	0.28	2.01	0.01	0.05	0.03	0.03
MGD			0.790							
LBS/DAY				≤0.061	1.29	47.81	<0.072	1.15	0.60	<0.77

TABLE E-34. OLD PARK ROAD TRUNKLINE, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/1)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
11-21-78	T	6P	0.067	<0.001	0.094	4.40	0.01	0.18	0.12	0.10
		8P	0.071	0.001	0.047	3.24	0.01	0.16	0.11	0.10
		10P	0.068	0.002	0.047	3.49	0.01	0.14	0.10	0.10
11-22-78	W	12A	0.058	0.002	0.075	4.75	0.01	0.15	0.11	0.12
		2A	0.058	0.007	0.211	6.87	0.01	0.21	0.10	0.10
		4A	0.050	0.003	0.034	2.59	0.01	0.15	0.06	0.10
		6A	0.054	0.002	0.126	14.28	0.01	0.15	0.05	0.10
		8A	0.068	0.001	0.615	9.16	0.01	0.16	0.10	<0.10
		10A	0.064	0.001	0.036	6.42	0.01	0.25	0.12	<0.10
		12P	0.064	0.002	0.040	9.03	0.01	0.19	0.10	<0.10
		2P	0.067	0.002	0.051	1.48	0.01	0.20	0.11	<0.10
11-15-78	W	4P	0.071	<0.001	0.024	0.61	<0.01	0.10	0.05	<0.10
MEAN			0.063	≤0.002	0.12	5.53	0.01	0.17	0.09	<0.11
STANDARD DEVIATION			0.007	0.002	0.17	3.87	0.00	0.04	0.02	0.01
MGD			0.753							
LBS/DAY				≤0.010	0.74	40.46	0.058	1.05	0.58	<0.39

TABLE E-35. OLD PARK ROAD TRUNKLINE, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/l)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN$^-$
11-15-78	W	6P	0.071	<0.001	0.015	0.43	<0.01	0.06	0.03	0.10
		8P	0.068	0.001	0.003	0.90	0.01	0.14	0.09	0.10
		10P	0.067	0.001	0.006	0.80	0.02	0.13	0.09	0.10
11-16-78	TH	12A	0.067	<0.001	0.033	0.73	0.01	0.14	0.07	0.10
		2A	0.056	<0.001	0.047	0.71	<0.01	0.13	0.06	<0.10
		4A	0.058	<0.001	0.066	0.91	<0.01	0.11	0.03	0.14
		6A	0.062	0.001	0.047	0.55	<0.01	0.08	0.04	0.19
		8A	0.075	0.001	0.027	0.48	0.01	0.13	0.08	<0.10
		10A	0.064	<0.001	0.034	0.33	0.01	0.10	0.08	0.13
		12P	0.067	<0.001	0.021	0.25	0.01	0.07	0.06	<0.10
		2P	0.068	0.001	0.029	0.24	0.01	0.17	0.10	0.11
		4P	0.068	0.007	0.040	1.05	0.01	0.47	0.11	0.10
MEAN			0.066	≤0.002	0.031	0.62	≤0.02	0.14	0.07	<0.11
STANDARD DEVIATION			0.005	0.002	0.018	0.27	0.01	0.11	0.02	0.03
MGD			0.791							
LBS/DAY				≤0.010	0.31	4.04	≤0.072	1.42	0.50	<1.75

TABLE E-36. PETE'S RUN INTERCEPTOR TRUNKLINE, SAMPLING DAY ONE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1)						
				Cd	Cr	Ni	Pb	Zn	Cu	CN^-
2-19-79	M	6P	0.120	0.002	0.009	0.03	0.02	0.25	0.24	<0.10
		8P	0.120	0.001	0.008	0.04	0.02	0.15	0.21	0.10
		10P	0.120	0.002	0.025	0.18	0.07	0.27	0.51	<0.10
2-20-79	T	12A	0.120	0.050	0.086	0.31	0.24	5.11	0.38	<0.10
		2A	0.100	0.001	0.016	0.07	0.04	0.27	0.24	<0.10
		4A	0.082	0.001	0.011	0.06	0.04	0.16	0.20	<0.10
		6A	0.082	0.001	0.008	0.03	0.01	0.06	0.12	<0.10
		8A	0.180	0.001	0.027	0.03	0.02	0.08	0.17	<0.10
		10A	0.180	0.001	0.006	0.01	0.01	0.09	0.18	<0.10
		12P	0.180	0.001	0.007	0.02	0.02	0.13	0.22	<0.10
		2P	0.137	0.002	0.010	0.03	0.02	0.19	0.21	<0.10
		4P	0.107	0.003	0.014	0.03	0.03	0.04	0.16	<0.10
MEAN			0.127	0.006	0.019	0.07	0.05	0.57	0.24	<0.10
STANDARD DEVIATION			0.036	0.014	0.022	0.09	0.06	1.43	0.11	0.00
MGD			1.528							
LBS/DAY				0.067	0.24	0.85	0.54	6.86	2.98	<1.27

TABLE E-37. PETE'S RUN INTERCEPTOR TRUNKLINE, SAMPLING DAY TWO

				METAL AND CYANIDE CONCENTRATIONS (mg/l)						
DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-26-79	T	6P	0.088	0.001	0.008	0.02	0.02	0.27	0.15	<0.10
		8P	0.089	0.033	0.195	0.34	0.49	4.64	0.77	<0.10
		10P	0.087	0.002	0.022	0.04	0.04	0.31	0.18	<0.10
6-27-79	W	12A	0.084	0.001	0.017	0.04	0.03	0.19	0.17	<0.10
		2A	0.064	0.003	0.008	0.02	0.02	0.13	0.13	<0.10
		4A	0.051	<0.001	0.007	0.02	0.01	0.24	0.11	<0.10
		6A	0.049	0.002	0.005	0.01	0.01	0.13	0.11	<0.10
		8A	0.058	<0.001	0.006	0.02	0.02	0.20	0.08	<0.10
		10A	0.089	0.002	0.003	0.01	0.02	0.20	0.11	0.10
		12P	0.098	0.004	0.008	0.03	0.04	0.26	0.18	<0.10
		2P	0.104	0.009	0.014	0.03	0.03	0.33	0.19	<0.10
		4P	0.100	0.002	0.017	0.04	0.04	0.22	0.20	<0.10
MEAN			0.080	≤0.005	0.026	0.05	0.06	0.59	0.20	<0.10
STANDARD DEVIATION			0.019	0.009	0.054	0.09	0.13	1.28	0.18	0.00
MGD			0.961							
LBS/DAY				≤0.045	0.23	0.45	0.56	5.38	1.69	<0.80

TABLE E-38. PETE'S RUN INTERCEPTOR TRUNKLINE, SAMPLING DAY THREE

DATE	DAY OF WEEK	TIME	MILLION GAL. OF FLOW/2H	METAL AND CYANIDE CONCENTRATIONS (mg/1) Cd	Cr	Ni	Pb	Zn	Cu	CN^-
6-27-79	W	6P	0.090	0.003	0.018	0.03	0.05	0.42	0.18	<0.10
		8P	0.118	0.002	0.019	0.11	0.09	0.41	0.29	<0.10
		10P	0.112	0.002	0.019	0.11	0.11	0.35	0.34	<0.10
6-28-79	TH	12A	0.107	0.001	0.019	0.10	0.09	0.19	0.26	<0.10
		2A	0.106	0.001	0.014	0.09	0.07	0.26	0.23	<0.10
		4A	0.082	0.001	0.014	0.10	0.07	0.20	0.26	<0.10
		6A	0.059	0.001	0.010	0.02	0.03	0.04	0.16	<0.10
		8A	0.089	0.001	0.012	0.09	0.09	0.17	0.19	<0.10
		10A	0.124	0.001	0.013	0.10	0.09	0.25	0.26	<0.10
		12P	0.132	0.001	0.017	0.11	0.07	0.19	0.27	<0.10
		2P	0.147	0.002	0.023	0.11	0.07	0.29	0.44	<0.10
		4P	0.163	0.003	0.014	0.03	0.03	0.04	0.16	<0.10
MEAN			0.111	0.002	0.016	0.083	0.072	0.23	0.25	<0.10
STANDARD DEVIATION			0.029	0.001	0.004	0.035	0.025	0.13	0.08	0.00
MGD			1.329							
LBS/DAY				0.018	0.18	0.95	0.80	2.61	2.89	<1.11